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PRESENT CONDITION OF THE NEW CAMPANILE AT VENICE

REBUILDING A FAMOUS VENETIAN TOWER [See Page 8.]

Weapons of Defense Among Animals

Their Function in the Struggle for Existence

One of the most significant factors in that struggle for existence which is the dominating law in the animal world is the method by which Nature secures the protection of the weaker creatures against the formidable attacks of the stronger. In a recent number of *Le Mois* the subject is discussed entertainingly by M. A. Ocloque, of whose article we present an abstract.

The larger carnivora, as he points out, possess such powerful weapons of offense that they have no need of that astonishing variety of arms and armor of defense possessed by less aggressive beings.

The lion, the tiger, the panther, and the wolf have formidable teeth and merciless claws. The bird of prey holds his victim in his talons as in a vise while tearing its flesh with its strong beak. The shark, with its four-yard spread of jaw, can sever the body of a man at one blow.

The octopus likewise maintains a pitiless clutch upon its prey with its snake-like arms and irresistible "suckers," while slowly draining its life juices. Such assassins, the aristocracy of carnage, as it were, would depopulate the world, but that, on the one hand, they are not very prolific, while on the other their victims are not only very fertile, as a rule, but are provided with the most various and ingenious means of defense.

All the *cœlenterata*, for instance, from the simple and solitary polyp; a mere sac furnished with tentacles, up to the *medusa* or *siphonophore*, possess in varying degree the power of striking the enemy by a sort of poisoned dart thrown from the irritating capsules developed in their tissues. At the least contact these capsules burst and project their tiny needle-like arrows, which are capable of giving a very painful and sometimes dangerous shock even to man.

Bathers know by experience how unpleasant it is to touch a stinging *medusa*, yet the *rhizostomes* of our coasts, born in cold climates hardly favorable to the elaboration of poisons, are mild and inoffensive as compared with the truly terrible *siphonophores* of the tropics. Little wonder that the vulgar parlance terms such creatures sea-nettles. The *medusa*, the sea-anemone, and the polyp are not the only creatures which possess this refined means of torture; these irritating capsules are also found in certain marine mollusks of the *nudibranch* group, whose soft and fragile bodies are not enveloped by a shell. Still other marine mollusks whose atrophied shell is an insufficient safeguard have the power of ejecting when irritated a purple liquid which is considered a very dangerous poison.

All the sting-bearing *Hymenoptera*, such as the bee and the wasp, have a very efficacious weapon in the envenomed stiletto which they can project from the abdomen at will. This sting is an instrument of the most delicate precision. Two valves protect it, united into a single piece whose lower side is indented by a channel in which rest the two "bristles" constituting the actual sting. This keen and effective little tool is supplied from two glands in the body of the insect, with a venom consisting essentially of formic acid and of an alkaline liquid, the mixture of the two being necessary to inflict the injury. The scorpion also pierces his enemy with the pointed end of the abdomen, and injects into the wound a drop of dangerous poison.

Some of the *Coleopterata* have a singular method of self-defense consisting in the projection against aggressors of a malodorous and caustic gaseous product issuing from the abdominal extremity. In many species this gaseous emission is accompanied by an explosion of some violence. The insect may be said to transform itself into a tiny pistol, and intimidates its adversary by the force of the discharge, besides repulsing it by the noxiousness of the projectile.

Most singular and amusing of all methods of self-defense are those which owe their efficacy entirely to their moral effect! Thus the little insect known as the staphilimus erects the end of its abdomen aggressively, though it has no sting, and at its utmost is only capable of projecting a gaseous emission whose odor is not always even disagreeable. Likewise the earwig profits by the fear occasioned by the formidable look of its abdominal pincers, which are really quite harmless. Equally curious is the habit of certain harmless little flies when seized by birds of so violently agitating the whole body that the captor, disconcerted and disagreeably affected by this intense vibration, is forced to open his beak and let the victim escape.

Certain of the carnivorous insects likewise profit by exciting disgust in the enemy by vomiting forth the half-digested and offensive contents of their stomachs.

Two analogous methods of astonishing and dismaying the aggressor are the habit of certain caterpillars of executing brusque and violent contortions and somersaults when seized, and the exceedingly curious custom of many vegetarian insects, which, when grasped, allow drops of blood to ooze from their articulations.

But most marvelous of all active modes of defense is the production and voluntary discharge by some fish of electricity in force sufficient to violently shock, or even kill, animals of large size. Three types are known to possess this power in a high degree—the *silurus*, the *gymnotus*, and the torpedo or cramp-fish.

The first inhabits the waters of the Nile and the rivers of Senegal, and is termed by the natives, who greatly fear it, the "thunder fish." Its battery is located between the muscles and the skin of the sides.

The *gymnotus*, likewise a fresh-water fish, is a sort of eel, inhabiting the marshes of South American rivers. It is quite common in the immense plains of the Orinoco. It attains a length of two meters, and is capable of giving a very dangerous shock. Humboldt gives an account of the ingenious method by which the Indians accomplish its capture. Horses and mules are driven into a swamp inhabited by the eels, which, excited by the unaccustomed noise, rise and discharge their terrible invisible weapons against the bellies of the unfortunate beasts used as decoys, some of which are killed before they can succeed in scrambling out panic-stricken from the zone of death. But after a certain lapse of time in this one-sided conflict, the eels have exhausted their batteries and can be safely harpooned, dragged to land and dispatched. The electric apparatus of this creature is located along the back and in the tail. That of the torpedo is composed of two large masses placed on either side of the body, under the skin of the back. These masses show on their surface a regular marquetry of tiny polygons, each of which represents the end of a little column of electrogenic plates or lamellæ, alternating with inert gelatinous plates. Thus is formed a sort of Voltaic "pile" or battery of considerable power.

M. Arsonval has recently made some experiments, with a view to measuring the intensity of the electricity generated by the torpedo. An individual of moderate size, i. e., of about three decimeters in diameter, is capable of producing at will a current varying from 2 to 10 amperes, with an electrometric force of from 15 to 20 volts. In these experiments an electric lamp of 10 candle-power, being connected with the electric organ of the torpedo, emitted a bright flash whenever the animal was irritated. The experimenter exhibited to the Académie des Sciences a lamp whose filament had been burned out by the discharge of a torpedo too violently excited. The stomach and the back of this fish are charged with opposite forms of electricity, and the shock is felt whenever connection is made between the two. From a physiological point of view the apparatus acts like a muscle which by a special adaptation furnishes electrical instead of mechanical energy. The curve representing the production of electricity which is emitted by a series of discharges all in the same direction and at intervals of about a hundredth of a second, is identical with the curve of contraction of a muscle. Moreover, the organ evolves heat during the discharge, if the current is closed upon itself, like a muscle performing mechanical work.

Passive modes of defense are not less varied than the active. One of the simplest and commonest forms of these consists in the inclosure of the soft and vulnerable parts of the animal in an envelope, which defies the attacks of enemies, either by its thickness, its hardness, its resistance or its protective protuberances or projections of various sorts.

The turtle withdraws its head, feet and tail into its osseous carapace, and thus braves all dangers. The hedge-hog, at the least alarm, rolls itself into a ball and presents an arrowed sphere to all aggressors. The sea-urchin shelters its soft body within a shell composed of numerous polygonal plaques, whence emerges a forest of needles pointing in every direction.

The external skeleton of insects plays an important part in their defense, but this sort of protective armor reaches its greatest degree of perfection in the *crustaceæ*, where the integument becomes a solid carapace abundantly fortified with calcareous matter, whose rigid parts, however, move with ease, thanks to the flexibility of their muscular attachments.

Crabs, lobsters, and creatures of their ilk, possess an armor which might be compared to that of the medieval warrior.

Finally, there is a vast class of animals which live as it were, within traveling castles of calcareous matter in the form of shells, which they drag painfully upon their backs from place to place, when they are able to change their location, but into which they can retire in time of danger as into a well-nigh impregnable stronghold. Sometimes this little castle is composed of a single tube, usually rolled into a spiral, as in the case of the snail; sometimes it is composed of two valves which can be opened or kept tightly closed at will. The orifice of the shell is sometimes provided with a bristling array of tooth-like projections intended to present an invincible obstacle to the hostile intrusion of predatory insects. Sometimes, on the other hand, it is the exterior of the shell which is covered with formidable spines laboriously secreted by the animal and meant to discourage those gluttonous fish which have the habit of swallowing mollusks, shell and all. The thorny shell of the "fine-spined" *murex* of the coasts of Ceylon, for example, doubtless offers as unpleasant possibilities to the mouth of a fish as the skin of a hedge-hog to the mouth of a dog.

In the case of naked mollusks, where the shell is atrophied or reduced to a mere calcareous plaque, other means of defense are often present, such as the production of the poisonous or irritant secretions above referred to. The most striking example, however, of this group, is that of the cephalopods—the octopus and other monsters of the same lineage. These brigands of the sea have a whole arsenal of weapons of offense and defense—a horny beak, a powerful set of muscles, the ability to change color if necessary, and most precious of all, the power of ejecting an inky fluid into surrounding water when an adversary is too redoubtable or the danger too pressing.

Occasionally, too, the shells of mollusks are borrowed as temporary or permanent places of refuge by animals to which they do not belong, as in the case of the little crabs which retreat within the shells of certain bivalves when threatened.

Many insects possess the instinct of fabricating, while in the larval state, dwellings of various substances, which serve both as shelters and hiding places. The pretty but pernicious labors of the larvæ of the ordinary moth are only too well-known to all the careless possessors of fur and woolen garments! Some caterpillars show a very remarkable ingenuity in constructing homes for themselves by cutting off and rolling together into cylindrical or conical form fragments of the leaves on which they feed, so that they achieve in one operation the three ends of nourishment, shelter, and protection for the period of metamorphosis. The larvæ of the insect *Psyche* construct very curious sheaths made of fragments of leaves, blades of grass, bits of straw, splinters of wood, and tiny stones, agglomerated by a paste mixed with threads of silk.

Highly interesting is the passive defense secured by many creatures through mimicry, in which both form and color play a part.

Sometimes this mimicry consists in the resemblance which a harmless creature bears to a formidable one, as in the similarity of an inert and stingless insect to one armed and irascible, like the wasp or the hornet. In other cases the mimicry consists in a deceptive resemblance to inert objects, such as twigs and leaves, or a similarity of color to the surroundings. This color protection is sometimes doubly effective because variable, as in the case of the chameleon. A less-known and very striking instance of this occurs in the octopus. Throughout its skin are disseminated tiny pigment cells of diverse colors, the *chromatophores*. In repose these bodies are rounded, contracted, and occupy small space. Consequently the coloration of the animal is clear. When, however, it receives an irritating impression, the muscular fibers which act on the *chromatophores* draw them out into the shape of stars, whose pigment-filled branches cause the color of the tissues to change to a somber gray. In this state the tone of the creature so blends with its sandy background that it becomes non-discernible to the unexpectant eye.

A form of protective mimicry analogous to some of the foregoing is the simulation of death, or "playing 'possum," practised by some animals and many insects.

The most simple and elementary means of defense is obviously mere flight, but this common aptitude has various modifications among various animals. In some, as in the hare and the kangaroo, tremendous speed has been developed. On sloping ground the latter is said to be able to cover 14 meters at a bound! Similarly, some insects, such as the flea, have the hind legs tremendously developed for the purpose

of making prodigious leaps. Those tiny crustaceans familiar to ocean bathers under the name of "sea-fleas" have the extremity of the abdomen modified into a saltatory organ.

But most curious and astounding of all, the phenomena observed in the development of the function of flight is that power of spontaneous amputation possessed by many species, and technically termed autotomy. The best-known example of this—perhaps the most startling phenomenon known to biology—is that of the lizard, which abruptly breaks loose its tail in order to escape. But the list of similar actions is almost inexhaustible, especially when the mutilation operates simply on very fragile organs.

But autotomy not merely permits flight. It defends the animal against the most diverse dangers. If the claw of a crab be subjected to some violent irritation, such as pinching, cutting or burning, it will detach itself abruptly in the vicinity of the sternal plastron and fall off. The animal thus avoids not only severe pain, but the danger and inconvenience of hemorrhage, which, abundant at any other part of the claw, is prevented by a membrane at the point of the autotomic rupture.

Two deep-sea starfish, *Aterias richardi* and *Solasterias neglecta*, spontaneously amputate their arms when invaded by the parasite *Myzostoruum asteriæ*.

Even more startling examples of the discarding of such organs as a lung or a digestive tube in case of pain or famine might be given did space permit. But we must close the subject with the observation that a corollary to this power of amputation is the associated power of regeneration with which many species are endowed, such as the starfish and sea-anemone, in whom a mere fragment suffices for the reconstitution of the individual.

Ocean Magnetic Work[*]

Some of Its Problems

By L. A. Bauer

THE PRINCIPLES FOLLOWED.

FROM the very start of the ocean magnetic work on the "Galilee" in 1905, two principles have been steadfastly held in view:

a. To get useful work done and make the results promptly known.

b. To strive toward the highest accuracy attainable in *all* elements consistent with *a.*

Early in 1905 I spent a month abroad consulting various eminent investigators as to the requirements of ocean work but could get practically no additional information to that which I had already obtained in my previous experience on Coast and Geodetic Survey vessels, magnetic work on board of which was begun under my direction in 1903.

It was concluded that the best procedure would be to make a beginning in the Pacific Ocean at once by selecting a suitable vessel to be chartered for a term of years. As the result of some advertising the "Galilee" was finally chosen and as much as possible of the iron on board removed or replaced by non-magnetic materials. Next a special observing bridge was constructed, on which the instruments were mounted. The result was that we had a vessel for which, at the places where the various magnetic instruments were placed, the deviation coefficients were the smallest of any ship thus far employed in magnetic work, inclusive of those specially constructed for Antarctic exploration, the "Discovery" and the "Gauss."[†]

We next strove toward a *symmetrical development* of all the instruments. It was recognized as a mistake to pick out anyone, e. g., an intensity instrument, and devote exclusive attention to it and disregard how it would fit in with the other appliances. Hence equal attention was bestowed from the start to all three elements, every known method and instrument being studied and thoroughly tried out under actual *sea* conditions. Thanks to my previous experience, it was possible during the period of the trial trip from San Francisco to San Diego in 1905 to settle on the methods which applied practically throughout the three years, 1905-08, the "Galilee" was in commission.

It was quickly shown that by the methods employed whereby each element was determined in two different ways with different instruments and by different observers, the observational errors were not only considerably less than the chart errors, but were also, in general, less than or about on the order of the error of the ship deviation corrections. In other words the uncertainty of the deviation correction very soon became our chief concern. And if this was true with the precautions taken on the "Galilee" having smaller deviation coefficients than any other vessel engaged in magnetic work, viz., swinging ship every third or fourth day, then how much more must it be true on a vessel having larger deviation coefficients and less opportunity for swings, as was the case with the recent Antarctic vessels?

What need was there, therefore, for deferring the getting of useful results until ocean instruments had reached the same state of perfection as land instruments, unless one were assured that funds would soon be available for the building of a wholly non-magnetic ship? This assurance we did not have when the work was begun on the "Galilee." In fact it was necessary to win confidence in our ability "to make good" what we had promised. And so we were determined to make the ocean work a success: Instead of spending three years or more in elaborate office investigations and writing memoirs we though it best to start right out and get some work done and, above all, make the results known promptly. By June, 1906, it was already possible to call attention to large systematic errors in the magnetic charts of the three elements for the Pacific Ocean. Early in the spring of 1907 all the data obtained were supplied to the United States Hydrographic Office on the understanding that new magnetic charts of the three elements were to be issued.

The prompt reduction of the observations and the many controls insisted on whenever the vessel reached port served to disclose the weak points, but not always as quickly as desired. Thus, because the deviation coefficients were different at the various positions of the instruments, it was not possible to get an immediate comparison, for example, in declinations made at two different stations on the ship. The deviation corrections could not be successfully determined until the completion of a cruise covering a large enough range in magnetic latitude. And here is where the great advantage of having a non-magnetic ship, like the "Carnegie," counts most heavily. It is now possible to make on board nearly a final computation a few minutes after completion of the observations and thus "check up" at once and repeat, if necessary.

THE INSTRUMENTS.

The available space on board ship for magnetic work is, necessarily, restricted and, in fact, is never as large as one would like—not even on the "Carnegie." Hence it becomes essential to arrange the instruments so that what is aimed for can be accomplished without bringing them so close as to have an effect on one another and thus introduce once more deviation corrections. There are three elements to be determined: declination, dip and intensity. My general experience in magnetic work has forcibly impressed upon me the need of getting a totally independent check on each element of observation. Hence each element is to be determined twice, simultaneously preferably, and so there either must be 3×2 or six different instruments or each instrument must be arranged to measure more than one element. The first suggestion is rarely practical because of the limited observing space and the desirability of taking advantage of the best possible conditions regarding steadiness of ship, etc.

Our developments have accordingly been along the second line: That each instrument should be capable of measuring at least two different magnetic elements.

Thus an instrument primarily intended for magnetic declinations was arranged, by a suitable deflection device, to measure also the horizontal intensity; one arranged chiefly for horizontal intensity was made so that declination could be observed with it, and finally the L. C. dip circle permitted getting both the dip and the total intensity. Thus it was possible to apply all needful checks and the instrumental equipment was such that the three magnetic elements could be determined wherever the vessel might happen to be. In regions of weak horizontal intensity it would be better to employ a total intensity method, hence there must be appliances for measuring both.

THE L. C. DIP CIRCLE.

Beginning with the L. C. dip circle the chief improvements made on the original instrument as devised by Capt. Creak and as supplied to the Antarctic expeditions were as follows:

Insistence on perfection in construction of the various parts of the instruments by the maker, A. W. Dover, of Charlton, Kent, notably of the pivots and jewels. It was impossible at first to get the Kew Obervatory to furnish dip corrections on their standard closer than 5′. Thus if the correction of one needle would actually be —2′.4 and another —7′.6, the Kew Observatory might give as correction of the respective needles 0′ and —10′. When questioned, it was stated that, as the observational error of these instruments was large, the observatory was not warranted in giving closer corrections. However, the observers trained by us reached an accuracy not so very far behind that with land dip circles and we, finally, succeeded, due to Dover's skill, in getting instruments for which the Kew Observatory was willing to give the differences on their standard at least to the nearest whole minute.

Next, it was found that the original deflection distance was a trifle short, and, in consequence, deflections were impossible when the earth's magnitude force fell below a certain value. Thus on the 1905 cruise the instrument became unavailable for intensity observations before the vessel reached Honolulu. A similar experience was encountered by the Coast and Geodetic Survey steamer "Bache" on a trip to Jamaica and Colon. Accordingly the distance was sufficiently increased and at the same time a second deflection distance introduced, making the instrument now everywhere available—something which the horizontal intensity instrument is not. A brass holder for the deflecting needle was made so as to avoid handling the needle during a set of observations, the passage from short distance to long distance being accomplished by a simple inversion of the holder, the needle being mounted eccentrically inside.

Next the milled heads of the footscrews were graduated and means provided for insuring that the instrument when mounted on the gimbal stand was actually level. The heights of the footscrews were repeatedly determined and controlled for an invariable and level position of the circle, whenever the sea was calm or when the vessel was in port and thus the instrument set level in between. I do not remember seeing described in any book on ocean magnetic work, how the dip circle was actually set level on the gimbal stand, although the full error of level may go into the dip. (An accidental missetting of the footscrews upon one occasion, by less than one complete turn, produced an error of about one degree and a half in the dip.)

The method of observation invariably followed yields four determinations of dip, two of these being with the regular dip needles according to the absolute method, inclusive of reversal of polarity of needle, and two being "deflected dips," i. e., those resulting from the deflection observations at two distances for getting total intensity, hence not involving any additional time. The scheme of observation is such that each dip applies practically to the same moment of time and to the same position of ship which of course is moving throughout the observations. At first the agreement between the directly observed dips and the deflected ones was not always satisfactory, but it was soon discovered that this was due to mechanical imperfections, which have since been remedied. Next two determinations of total intensity, using two deflection distances, are obtained. Should one wish, the scheme can readily be extended to include different sets of needles, etc.

(To be continued.)

[*] *Terrestrial Magnetism and Atmospheric Electricity.*

[†] Certain papers, which have recently come to my attention, show that it is difficult even for a magnetician skilled in observatory or land work, much less a layman, to form an adequate conception of the problems confronting one in ocean work. I have though it, therefore, not amiss to publish these remarks, even though they must be in somewhat fragmentary form. I have been on the point of writing them out more fully several times, but have been prevented for various reasons.

Title Pages for the Scientific American Supplement

THE present number of the SCIENTIFIC AMERICAN SUPPLEMENT marks the beginning of a new volume. Contrary to our practice in former years, we have not included the usual volume title page. Those of our readers who wish to bind up the last volume will receive a title page on application to this office.

Multiplex Telephony and Telegraphy—I*

Electric Waves Guided by Wires

By George D. Squier

Electrical transmission of intelligence, so vital to the progress of civilization, has taken a development at present into telephony and telegraphy over metallic wires; and telegraphy, and, to a limited extent, telephony, through the medium of the ether by means of electric waves.

During the past twelve years the achievements of wireless telegraphy have been truly marvelous. From an engineering viewpoint the wonder of it all is that with the transmitting energy being radiated out over the surface of the earth in all directions, enough of this energy is delivered at a single point on the circumference of a circle, of which the transmitting antenna is approximately the center, to operate successfully suitable receiving devices by which the electromagnetic waves are translated into intelligence.

The "plant efficiency" for electrical energy in the best types of wireless stations yet produced is so low that there can be no comparison between it and the least efficient transmission of energy by conducting wires.

The limits of audibility, being a physiological function, are well known to vary considerably, but they may be taken to be in the neighborhood of 16 complete cycles per second as the lower limit and 15,000 to 20,000 cycles per second as the upper limit. If, therefore, there is impressed upon a wire circuit for transmitting intelligence harmonic electromotive forces of frequencies between 0 and 16 cycles per second, or, again, above 15,000 to 20,000 cycles per second, it would seem certain that whatever effects such electric wave frequencies produced upon metallic lines, the present apparatus employed could not translate this effect into audible signals.

There are, therefore, two possible solutions to the problem of multiplex telephony and telegraphy upon this principle by electric waves, based upon the unalterable characteristic of the human ear, viz., by employing (1) electric waves of infra-sound frequencies, and (2) those of ultra-sound frequencies. One great difficulty in designing generators of infra-sound frequencies is in securing a pure sine wave, as otherwise any harmonic of the fundamental would appear within the range of audition. Furthermore, the range of frequencies is restricted, and the physical dimensions of the tuning elements for such low frequencies would have a tendency to become unwieldy.

The electromagnetic spectrum at present extends from about four to eight periods per second, such as are employed upon ocean cables, to the shortest waves of ultra-violet light. In this whole range of frequencies there are two distinct intervals which have not as yet been used, viz., frequencies from about 3×10^{12} of the extreme infra-red to 5×10^{10}, which are the shortest electric waves yet produced by electrical apparatus, and from about 80,000 to 100,000 cycles per second to about 15,000 to 20,000 cycles per second. The upper limit of this latter interval represents about the lowest frequencies yet employed for long distance wireless telegraphy.

Within the past few years generators have been developed in the United States giving an output of two kilowatt and more at periods of 100,000 cycles per second, and also capable of being operated satisfactorily at as low a frequency as 20,000 cycles per second. Furthermore, these machines give a practically pure sine wave.

The necessary condition for telephony by electric waves guided by wires is an uninterrupted source of sustained oscillations, and some form of receiving device which is quantitative in its action. In the experiments described in multiplex telephony and telegraphy it has been necessary and sufficient to combine the present engineering practice of wire telephony and telegraphy with the engineering practice of wireless telephony and telegraphy.

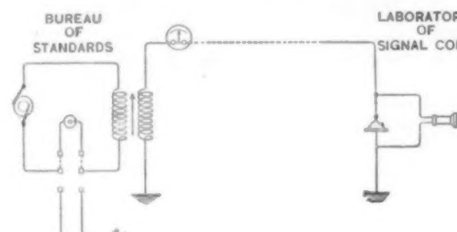


Fig. 1

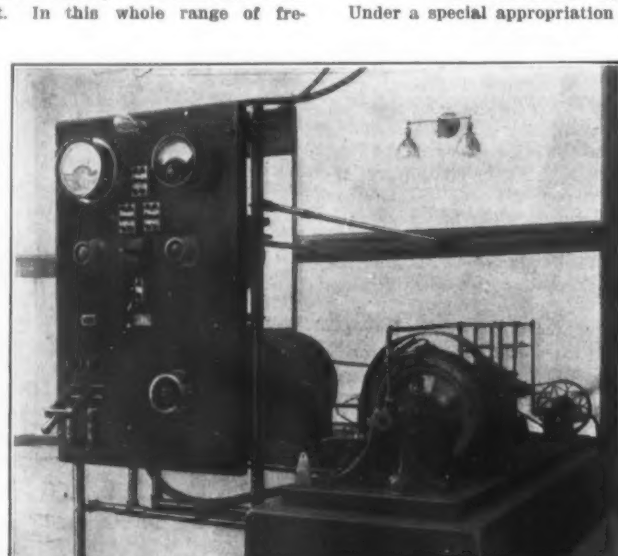
The frequencies involved in telephony over wires do not exceed 1,800 to 2,000, and for such frequencies the telephonic currents are fairly well distributed throughout the cross section of the conductor. As the frequency is increased the so-called "skin effect" becomes noticeable, and the energy is more and more transmitted in the ether surrounding the conductor.

It has been found possible to superimpose, upon the ordinary telephonic wire circuits now commercially used, electric waves of ultra-sound frequencies without producing any harmful effects upon the operation of the existing telephonic service. Fortunately, therefore, the experiments described below are constructive and additive, rather than destructive and supplantive.

Electric waves of ultra-sound frequencies are guided by means of wires of an existing commercial installation and are made the vehicle for the transmission of additional telephonic and telegraphic messages.

Apparatus and Equipment.

Under a special appropriation granted to the Signal Corps by Congress in the Army Appropriation Act of 1909, a small research laboratory has been established at the Bureau of Standards, in the suburbs of the city of Washington. This laboratory is equipped with the latest forms of apparatus now employed in the wireless telephone and telegraph art, and also with the standard types of telephone and telegraph apparatus now used upon wire circuits. The small construction laboratory of the United States Signal Corps is located at 1710 Pennsylvania Avenue and is also equipped with the usual types and forms of apparatus used in transmitting intelligence by electrical means. Each of these laboratories is supplied with a wireless telephone and telegraph installation with suitable antennæ. In addition, these two laboratories are connected by a standard telephone cable line about seven miles in length, which was employed in the experiments described below.



FRONT VIEW OF HIGH-FREQUENCY ALTERNATOR, DRIVING MOTOR AND SWITCHBOARD

The 100,000-Cycle Generator.

The high-frequency alternator, which is shown complete with driving motor and power panel in the accompanying illustrations, is a special form of the inductor type designed for a frequency of 100,000 cycles with an output of two kilowatts, making it adapted for use in wireless telephony or telegraphy.

Driving Motor.—The motor is a shunt-wound 10 horse-power machine with a normal speed of 1,250 revolutions per minute. It is connected by a chain drive to an intermediate shaft which runs at a speed of 2,000 revolutions per minute. The intermediate shaft drives the flexible shaft of the alternator through a De Laval turbine gearing, having a ratio of ten to one. The flexible shaft and inductor thus revolve at a speed of 20,000 revolutions per minute.

Field Coils.—The field coils, mounted on the stationary iron frame of the alternator, surround the periphery of the inductor. The magnetic flux produced by these coils passes through the laminated armature and armature coils, the air gap, and the inductor. This flux is periodically decreased by the nonmagnetic section of phosphor-bronze imbedded radially in the inductor of its periphery.

Armature Coils.—The armatures or stators are ring-shaped and are made of laminated iron. Six hundred slots are cut on the radial face of each; a quadruple silk-covered copper wire, 0.016 inch (0.4 millimeter) in diameter, is wound in a continuous wave up and down the successive slots. The peripheries of the armature frames are threaded to screw into the iron frame of the alternator. By means of a graduated scale on the alternator frame the armatures can be readily adjusted for any desired air gap.

Inductor.—The inductor or rotor has 300 teeth on each side of its periphery, spaced 0.125 inch (0.491 millimeter) between centers. The spaces between the teeth are filled with U-shaped phosphor-bronze wires, securely anchored, so as to withstand the centrifugal force of 80 pounds (36.2 kilogrammes) exerted by each. Since each tooth of the inductor gives a complete cycle, 100,000 cycles per second are developed at 20,000 revolutions per minute. The diameter of the disk being one foot (0.3 meter), the peripheral speed is 1,047 feet (319 meters) per second, or 700 miles per hour, at which rate it would roll from the United States to Europe in four hours. By careful design and selection of material, a factor of safety of 6.7 is obtained in the disk, although the centrifugal force at its periphery is 68,000 times the weight of the metal there.

Bearings.—The generator has two sets of bearings, as shown in the illustrations, the outer set being the main bearings which support the weight of the revolving parts. These bearings are self-aligning and are fitted with special sleeves, which are ground to coincide with longitudinal corrugations of the shaft, thus taking up the end thrust. A pump maintains a continuous stream of oil through these bearings, thus allowing the machine to be run continuously at full speed without troublesome heating.

The middle bearings normally do not touch the shaft, but take up excessive end thrust and prevent excessive radial vibration of the flexible shaft.

An auxiliary bearing or guide is placed midway between the gear box and the end bearing. Its function is to limit the vibration of that portion of the shaft.

Critical Periods.—In starting the machine, severe vibration occurs at two distinct critical speeds, one at about 1,700 and the other at about 9,000 revolutions per minute. The middle bearings prevent this vibration from becoming dangerous.

Voltage.—With the normal air gap between the armatures and revolving disk of 0.015 inch (0.059 millimeter), the potential developed is 150 volts with the armatures connected in series. It is possible, however, to decrease the air gap to 0.004 inch (0.015 millimeter) for short runs, which gives a corresponding increase in voltage up to nearly 300 volts. It is considered inadvisable, however, to run with this small air gap for any considerable length of time.

The machine is intended to be used with a condenser, the capacity reactance of which balances the armature inductance reactance which is 5.4 ohms at 100,000 cycles. This would require a capacity of about 0.3 microfarad for resonance at this frequency,

* A paper presented at the 28th Annual Convention of the American Institute of Electrical Engineers, Chicago, Ill., June 26th-30th, 1911.

but in the experiments conducted at 100,000 cycles it was found necessary to decrease this amount on account of the fixed auxiliary inductance of the leads.

CONSTANTS OF THE TELEPHONE LINE.

The telephone line used in these experiments extends from the Signal Corps laboratory at 1710 Pennsylvania Avenue to the Signal Corps research laboratory at the Bureau of Standards.

This line is made up of the regular standard commercial equipment and consists of paper-insulated, twisted pairs in lead-covered cable, placed in conduit in the usual manner employed for city installation. For the sake of convenience one of the pair is designated as No. 1 wire and the other as No. 2 wire.

The air-line distance between the two laboratories is a little over three miles (4.8 kilometers), but the telephone line, by passing through three exchanges, covers about seven miles (11.26 kilometers). The course of the line, with the size and type of conductor, is as follows:

Laboratory to Main Exchange, underground cable, No. 22 B. & S. Main Exchange to West Exchange, underground cable, No. 19 B. & S.

West Exchange to Cleveland Exchange, underground cable, No. 19 B. & S.

Cleveland Exchange to Bureau of Standards, underground cable, No. 19 B. & S.

Underground cable except from Bureau of Standards to Wisconsin Avenue and Pierce Mill Road, about 3,400 feet, which is aerial cable.

This line is equipped with protective heat coils of a standard type, one in each wire of the metallic circuit, at the Cleveland Exchange and the Main Exchange, but none at the West Exchange. The constants of each of these coils are as follows:

Direct current resistance of 65 deg. F. ....3.8 ohms
Size of wire ....No. 30 B. & S.
Length of wire................40 centimeters
Number of turns in each coil, about 38
Measured inductance at 70,000 cycles ....4,400 centimeters or 4.4×10^{-6} henry

The above constants were measured from a sample of one of these coils selected at random.

Resistance of metallic circuit..=776 ohms
Capacity measured (one minute electrification) between No. 1 and No. 2 wires..........=0.69 microfarad
Insulation resistance:
Between No. 1 wire and earth..=0.9 megohms
Between No. 2 wire and earth..=1.3 megohms
Between No. 1 and No. 2 wires in parallel and earth........=0.8 megohms
Between No. 1 and No. 2 wires.=2.1 megohms

The line included the usual house-wiring at each station, which was undisturbed in taking the measurements.

II. DUPLEX-DIPLEX TELEPHONY OVER WIRE CIRCUITS.

Such has been the development of telephone engineering that at present any proposal which requires for its success the supplanting of the present low frequency battery system would be most radical. It would surely be admitted that any plan which permits the present engineering telephone system to remain intact and superimpose thereon additional telephone circuits would possess cardinal advantages. Accordingly, the first preliminary experiments were directed to the inquiry as to whether or not it is possible to superimpose upon the minute telephonic currents now employed in telephony over wires, electric waves of ultra-sound frequencies without causing prohibitive interference with the battery telephone currents. Manifestly, this fundamental point can best be determined by experiments, at the generator itself, with the most sensitive part of the telephone equipment, viz., the telephone receiver. Accordingly, experiments were first conducted with various forms and types of telephone receivers in connection with local circuits at the generator. Such is the sensibility of the telephone receiver that it was thought possible that, although currents of frequencies entirely above audition were applied to the receiver from a dynamo as a source, there might be some frequency or frequencies from the operation of the apparatus which would be within the range of audition. Such was found, in fact, to be the case at certain critical frequencies of the machine, but they were of no practical importance, as will be shown later.

With a collection of telephone receivers ranging from about 50 to over 8,000 ohms and of a variety of design, a series of tests was made under severe conditions to determine the above point. It was found, in general, that alternating currents of frequencies ranging from 30,000 to 100,000 complete cycles per second, when coupled directly, inductively, or electrostatically to local circuits from the generator produced absolutely no perceptible physiological effects in the receivers, excepting only that at certain of the lower frequencies a distinct audible note could be faintly heard in one of the receivers of about 250 ohms resistance.

A search for the cause of this note showed that it is due to a slight variation of the amplitude of the high-frequency current of the generator, since no evidence of it could be detected on the battery telephone side of the circuit. It appears to be caused by a very slight vibration of the rotor as a whole in the magnetic field of the generator. It was almost entirely removed by the simple device of opening out the stators, which increases the clearance and materially cuts down the flux of the machine. In practice it is a distinct advantage, however, to have a trace of this note still left on the high-frequency side of the circuit, otherwise there is no ready means of determining at the receiving end of the cable line

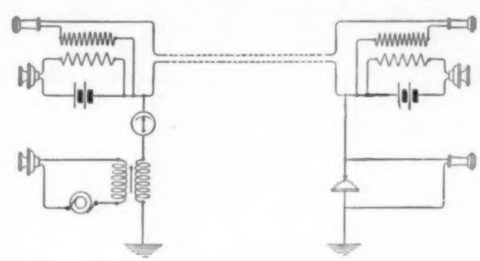


FIG. 2

whether or not the high-frequency current is present on the line, whereas this note, which has to be searched for in tuning and which was entirely tuned out when speech was best, gave a very convenient method of testing for the presence of high-frequency current.

Having determined the general nature of this disturbance and its comparative unimportance, no further investigation of it was considered necessary at that time.

The next fundamental point to determine was whether or not at these frequencies a telephone can receive enough energy to make it operative for producing sound waves in air.

Since the self-induction of a standard telephone receiver is high, energy at these frequencies is effectively barred from it. In the wireless telegraph art, where the frequencies involved are from one thousand to several million per second, this problem has been uniformly solved by the introduction of some form of detector for electromagnetic waves, whose function is to transform the energy of the high-frequency oscillations into other forms suitable to a type of instrument such as a telephone receiver.

The next step, therefore, consisted in introducing various forms of detectors, such as are now used in wireless telegraphy, between the telephone receiver itself and the energizing circuit. Since the frequencies being here considered are entirely above audition, the ear in a form well suited for physiological effects. Since it is well known that the human ear is most sensitive at a period of about 500 cycles per second, or 1,000 alternations, interrupters giving this frequency were employed.

The presence of the detectors in this chain of transformations is necessitated by the use of the telephone receiver as a translating device.

Although some of the detectors for electric waves are very sensitive to electrical energy, they are here employed not because they are more sensitive to electrical energy than is the telephone receiver itself, which is not the case, but because the telephone receiver is not adapted, for the reasons stated above, to translate electrical energy of these frequencies into movements of its diaphragm.

The elements of the apparatus thus far include a generator of sustained high-frequency oscillations, an interrupter to modify the amplitude of these oscillations into groups of a period within the range of audition, some form of detector to rectify these oscillations, and a telephone receiver. Manifestly here are all of the elements that are necessary for telegraphy, using the telephone receiver to interpret the signals.

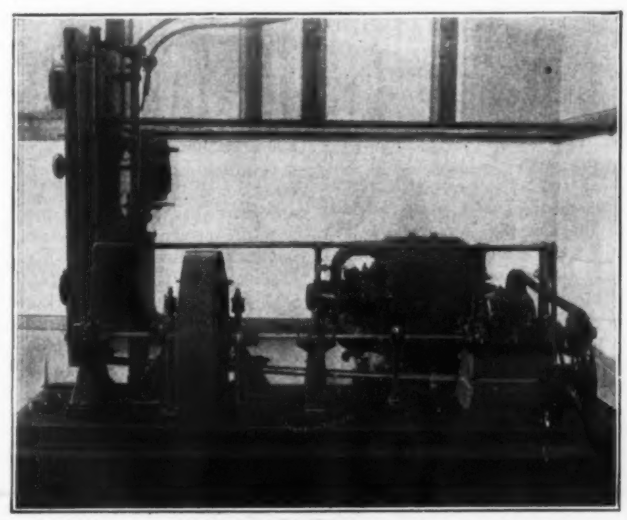
If in the above-mentioned chain of apparatus the interrupter is replaced by some form of telephone transmitter, such as the microphone, this is all that is necessary for the transmission of speech.

Experiments were made over local circuits with apparatus arranged in this order over a range of frequencies from 20,000 to 100,000, with the result that speech was transmitted very satisfactorily. Upon removing the detector from the above arrangement all perceptible effect in the telephone receiver ceased; in fact, no arrangement of connections of a telephone receiver to such a high frequency circuit which did not include some form of detector was found to be operative for telephony, unless certain low resistance telephones were used, in which case the speech was so much weaker as to be of an *entirely different order of magnitude.*

The presence of a detector in this chain of operations is not absolutely necessary in the case of telegraphy, since if the interrupter automatically produces a definite number of wave-trains per second, each train consisting of at least several complete oscillations, an effect may be produced upon a telephone receiver directly without a detector. The physiological effect, however, is quite different, the clear fundamental note corresponding to the frequency of the interrupter being no longer audible, but, instead, a peculiar dull hissing sound. If, however, a telephone receiver was used, which, instead of having a permanent magnet as a core, had one of soft iron, no effect without the detector was produced with the energy used.

As stated above, in the case of telephony, the energy required for telegraphy without a detector is of a different order of magnitude.

Having determined the necessary and sufficient conditions for the accomplishment of telegraphy and telephony by means of electric waves guided by wires upon local circuits, the next step was to apply these means and conditions to an actual commercial telephone cable line, constants of which are given above.



REAR VIEW OF HIGH-FREQUENCY ALTERNATOR, DRIVING MOTOR AND SWITCHBOARD

it was necessary, in order to produce a physiological effect, to introduce another element in this transformation, viz., some method of modifying the continuous train of sustained oscillations from the generator into groups or trains, the period of which falls within the limits of audition. This was accomplished by employing the regular forms of automatic interrupters, such as are now used in wireless telegraphy, with the expected result that with these two additional and essential pieces of apparatus operatively connected between the telephone receiver and the generator, the energy of the generator was delivered to

The machine was run at a frequency of 100,000 cycles per second, with the circuit arrangements as shown in Fig. 1, where one wire of the telephone cable was connected to one terminal of the secondary of an air-core transformer, the other terminal being connected to earth.

At the receiving end of the line, which was the Signal Corps construction laboratory, at 1710 Penn-

sylvania Avenue, Washington, D. C., this wire was connected directly to earth through a "perikon" crystal detector, such as is well known in wireless telegraphy, and a high resistance telephone receiver of about 8,000 ohms was shunted around the crystal. In this preliminary experiment no attempt was made at tuning, either at the transmitting end or at the receiving end of the line.

In the primary circuit of the generator, arrangements were made by which either an interrupter and telegraph key or a telephone transmitter could be inserted by throwing a switch.

In the line circuit a hot wire milliammeter was inserted in a convenient position, so that the effect of the operation of either the telegraph key or of the human voice upon the transmitter could be observed by watching the fluctuations of the needle of the milliammeter.

A loose coupling was employed between the two circuits at the transmitting end, and the line circuit adjusted by varying the coupling until the current in the line was twenty to thirty milliamperes. With this arrangement (1) telegraphic signals were sent and easily received, and (2) speech was transmitted and received successfully over this single wire with ground return.

The ammeter showed marked fluctuations from the human voice, and enabled the operator at the transmitting station to be certain that modified electric waves were being transmitted over the line.

The actual ohmic resistance of the line apparently played an unimportant part for telegraphy at 100,000 cycles, since with one of the wires of the pair and a ground return, the effect of doubling the conductivity of the wire by joining both wires in parallel, although this arrangement increased the capacity of the wires, could not be detected with certainty by an operator listening to the signals and unaware of which arrangement was being used.

Inserting in the line wire a non-inductive carbon rod resistance of 750 ohms, which is practically the resistance of the line itself, could not be detected by any change in the intensity of the received signals.

The next experiment was to determine what effect, if any, such sustained electrical oscillations would have upon the minute telephonic currents employed in battery telephony.

(To be continued.)

Radiant Energy and Matter—IV*

Sir J. J. Thomson's Royal Institution Lectures

Continued from Supplement No. 1851, page 395

IN opening his fourth lecture of the series on "Radiant Energy and Matter," at the Royal Institution, Sir Joseph said that on the last occasion he had discussed the distribution, in its spectrum, of the energy radiated from a hot body. He had shown that this energy was distributed throughout the entire spectrum, which extended from a wave length almost infinitely long on the one side to a wave length almost indefinitely short on the other. The energy, however, in each case was particularly localized at one particular place, and in regions but a little removed from this point the energy might be exceedingly small. It was, in fact, difficult to convey by mere arithmetic an adequate idea as to how rapidly the energy died away toward the violet side of the spectrum. Take, for instance, he said, a body at the temperature of a warm room, or about 300 degrees absolute, and another body at a red heat, or 900 degrees absolute. Then the higher the temperature the shorter was the wave length of maximum energy, this wave length being inversely proportionate to the absolute temperature. In the former case the distribution of energy in the spectrum was represented by the diagram, the wave length of maximum energy being 10μ. At 900 degrees, on the other hand, the wave length of maximum energy was 3.3 μ. Now a box of photographic plates exposed to radiation given out at the lower of the temperatures would keep indefinitely, while a fraction of a second's exposure to radiation from a source at 900 deg. C. would affect them.

To a considerable degree it was possible, he went on, to compensate for feebleness of photographic action by increasing the time of exposure, and so that if the product, of the time of exposure and the strength of the light, was constant, the photographic effect was nearly the same. If, then, radiation from a source at 900 degrees K would affect the plates in one second, it was possible to calculate the time needed for light from a source at 300 degrees K to affect the plates, on the assumption that the effective waves were all shorter than 0.5 μ. It turned out, on making the calculation, that if the most extravagant estimate of the life of the earth was taken, and multiplied by 1,000, the resultant time would still not be enough for the low temperature radiation to produce the same photographic effect as that accomplished, in one second, by radiation from a source at 900 degrees absolute. This was due simply to the fact that 0.5 μ was much nearer to 3.3 μ than to 10 μ, which represented the wave lengths of maximum energy in the two cases. Such an example illustrated well how exceedingly rapidly the energy died away on the violet side of the spectrum.

The determination of the exact shape of this curve of energy, the lecturer continued, was important, and various attempts had been made to find its equation. One which fitted in very well with observation had been given by Lord Rayleigh, but that most used was due to Planck, and might be written

$$E_\lambda \propto \frac{\lambda^{5}}{e^{\frac{c}{\lambda\theta}}-1},$$

and the speaker had himself given the following:

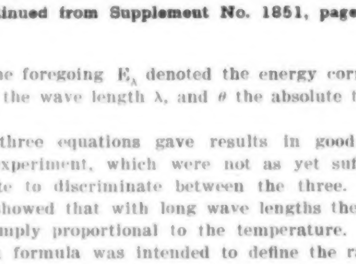
$$E_\lambda \propto \frac{\theta}{\lambda^4} I_0^{2}\left(\frac{1}{\lambda\theta}\right),$$

where $I_0\left(\frac{1}{\lambda\theta}\right)$ denoted a Bessel function of the zeroeth order, and having an imaginary argument.

In the foregoing E_λ denoted the energy corresponding to the wave length λ, and θ the absolute temperature.

All three equations gave results in good accord with experiment, which were not as yet sufficiently accurate to discriminate between the three. All of them showed that with long wave lengths the energy was simply proportional to the temperature.

Each formula was intended to define the radiation from an ideal black body. Such a body was not easily procured, and it had been necessary to find an equivalent which depended upon a certain relation existing between the radiation emitted and absorbed by a body. In the first place, he would recall that the radiation emitted from a body depended only on its



Distribution of Energy in the Radiation From a Body at Room Temperature, 300 Degrees Absolute

temperature. Even if the latter were constant, the body was still radiating, and the reason it did not alter in temperature was because it received and absorbed an equal amount of energy which was radiated to it from surrounding objects. There was thus a dynamic equilibrium between income and expenditure of energy—a principle known as Prévost's theory of exchanges.

A body placed in an inclosure maintained at a constant temperature would ultimately attain the temperature of that inclosure, and there must thus be a close connection between the radiation it emitted and absorbed at a given temperature. In fact, if the temperature of the body remained constant, it must give out just as much energy as it absorbed. It followed, therefore, that a good radiator must be a good absorber, and *vice versa* a transparent body which absorbed little would also be a bad radiator. This relation, Prof. Thomson said, held out merely for the totality of the energy of the radiation, but also for each particular component of the spectrum.

Further, within an inclosure at constant temperature the character of the radiation must be everywhere the same. That this was so could be seen by assuming the contrary, and that at the top of an inclosure, for example, the radiation contained an excess of blue light, and at the bottom of red. If, then, a piece of blue glass were placed at the bottom of the inclosure, this would be a good absorbent of the red rays. Immersed in these rays it would ultimately attain the temperature of the inclosure, and would then send out as much energy as it received. If next it were transferred to the top of the inclosure, where *ex hypothesi* the temperature was the same, but the radiation had a blue character, it would radiate exactly as much as before, but being a poor absorbent for blue rays, would receive less energy than it sent out. Its temperature would consequently fall below that of the inclosure, a phenomenon which was contrary to experience.

Hence in such an inclosure a body, whatever its nature, must send out exactly the same kind of radiation as it received. Now an ideal black body would absorb all the radiation which fell upon it in such an inclosure, while its own radiation would be that of a perfectly black body. From this it followed, since radiation and absorption were, as had been shown, necessarily the same, that the radiation within such an inclosure must be that of an ideally black body, whatever the nature of the walls of the inclosure.

The term "black body," as used above, was not, the speaker said, well chosen, since the interior of such an inclosure might be very luminous. It would be better to adopt the term "full" radiation rather than black radiation. To obtain this it was merely necessary to make a small opening in the walls of an inclosure; the radiation that came through this being then the "full" radiation.

It was of interest to note that inside an inclosure maintained at constant temperature bodies lost their apparent outlines. A salamander inside a red-hot oven, completely closed, could, the lecturer said, see nothing of other objects within the same space, all outlines of bodies, so soon as they attained the temperature of the inclosure, disappearing in a uniform glare. So long as anything could be seen within such an inclosure the temperature could not everywhere be the same, provided always, he added, that chemical actions were absent.

Prof. Tyndall had, Sir Joseph proceeded, shown the connection between radiation and absorption in a very simple way. A Leslie cube, filled with hot water and having one face polished and the other black, was placed between two parallel plates. The plate opposite to the bright face of the cube was black, and that opposite the black face of the cube was polished. Under these conditions it was found that the temperature attained by the two plates was the same. The black face of the cube radiated a good deal more than the bright, so that more energy fell on the polished plate than on its fellow. Of this, however, it reflected the greater part, absorbing little, while the black plate, though it received little, absorbed it all, and the result, as stated, was that the temperature of the two plates remained the same. This experiment led directly to the formal expression of the fundamental law between radiation and emission.

Thus if E_B denoted the emission from a black body, and E_s that from a shining one, while R_s denoted the proportion of incident energy reflected from the bright face, we had going into the black body, and absorbed there, energy equal to $E + R_s E_B$. This was equal to the energy emitted by the black body, whence

$$E_s = E_B(1 - R_s),$$

or $\frac{E_s}{1 - R_s} = E_B$ the radiation from a black body at the same temperature.

Again, if A_s were the proportion of the incident energy absorbed, we had $A_s + R_s = 1$, from which we got $E_s = A_s E_B$.

Thus, if we took any object at any temperature, the amount of radiation it emitted was precisely that which it would absorb from a black body at the same temperature.

The above laws, and the fact that the radiation within an inclosure was the "full" radiation, were usually associated solely with the name of Kirchhoff, who had indeed developed their consequences with the greatest ability. This, however, he thought, did rather less than justice to the work of his old teacher, Balfour Stewart, who had published a proof of the same theorems one or two months before Kirchhoff. Both physicists had made many experiments to test the laws, in some cases practically identical ones. The behaviour of tourmaline, for example, had

* Report, as published by *Engineering*, of Sir. J. J. Thomson's series of lectures delivered before the Royal Institution.

been investigated by both. This body had the property of absorbing light polarized in one plane, while it was transparent to the complementary ray. From the law that absorption and emission were equal, it followed that heated tourmaline should emit polarized radiation, and this was proved to be the case.

Another important consequence of the laws set forth above was that, if thick enough, all bodies must emit "black" radiation. A mass of glass thick enough to absorb all the light on it must therefore give out the same kind of radiation as lamp black.

Continuing, the lecturer said that the absorption of radiation was nearly always selective, rays of different wave lengths being absorbed unequally. Glass, for instance, was very transparent to ordinary light, but was opaque to the radiation from bodies at moderate temperatures. To illustrate this, the lecturer allowed the radiation from a Leslie cube filled with hot water, and also that from a limelight, to fall on opposite faces of a thermopile, shifting the latter till the two faces were equally heated by the radiation they received. On next interposing similar sheets of glass between each source and the face of the pile it illumined, he showed that the balance was destroyed, the glass obstructing the passage of the low-temperature radiation much more than it did that from the limelight. This peculiarity of glass, he said, had been advanced as an explanation of the high temperature of green houses. The radiation from the sun passed easily through the glass into the house, but the low-temperature radiation, from the warmed earth within, was trapped by the opaqueness of the glass to such radiation. Prof. R. W. Wood had, however, cast doubt upon the adequacy of this evplanation, the effect in question being, in reality, small compared with that resulting from the imprisonment of the warmed air. Roofing a model greenhouse with rock salt instead of with glass, Prof. Wood had found that the temperature attained inside was rather higher than when the rock salt was replaced by glass, although the rock salt was very transparent to low-temperature heat. The higher temperature attained, when the rock salt was used, arose from the fact that, being more transparent than glass, it allowed more heat to enter in the first place.

Glass was not alone in possessing the property of absorbing low-temperature radiation. Gases also exhibited the same phenomenon, and water vapor in an especial degree. The last fact was discovered by Tyndall, and led to a long controversy with Magnus, who denied the fact, as to which, however, it was now known that Tyndall was perfectly right. Ammonia had a similar property, and this the lecturer showed by arranging a tube with rock salt ends between a thermopile and the face of a Leslie cube. Introducing a mere trace of ammonia vapor into this tube causes, he showed, a large deflection of the galvanometer connected to the thermopile.

It was, he continued, remarkable that a mixture of nitrogen and hydrogen, in the same proportions as they existed in ammonia, showed very little absorbing power, the property being one conveyed by chemical combination. Some of Tyndall's experiments on this head would, he thought, repay further investigation. Air passed over various scents, and musk in particular, was found by Tyndall to have its powers of absorption greatly increased. The phenomena observed might perhaps have been complicated by the presence of water vapor, but as the experiment stood, the absorption was the most remarkable on record.

Another gas with remarkable powers of absorption was CO_2, and this had been applied by Arrhenius to explain in a most ingenious way a long-standing crux of geologists as to the cause of the glacial epochs, when a freezing temperature existed almost down to the equator. Arrhenius suggested that the temperature varied with the amount of CO_2 in the atmosphere at different epochs. This gas absorbed low-temperature heat very strongly, and would thus imprison the energy received from the sun. An increase in the amount of CO_2 would thus cause the temperature to go up, while a decrease would mean a reduction of the temperature. Arrhenius calculated that a very remarkable fluctuation in the mean annual temperature (as much as 8 deg. to 9 deg. C.) might thus be produced by quite reasonable variations in the amount of this gas contained in the atmosphere, a few millions tons being thus sufficient to account for great changes of temperature. This hypothesis, at any rate, did not, the lecturer concluded, necessitate the play of such gigantic forces as certain rival theories which involved a shift in the position of the earth's axis.

The Sun's Distance

By J. H. Ogburn, Associate Professor Mathematics and Astronomy, Lehigh University

To the average individual the stars and astronomy in general are a source of much wonder and speculation which approach fascination when the mind is allowed to dwell on problems suggested by the scenes of glory presented even to the unaided eye.

No science perhaps deals with so many abstract ideas which must be adjusted into a system completely filling the conditions of time, distance and motions of the various celestial bodies; and these facts must be taken from the known laws of natural philosophy. A realization of how complicated a process this must be, often deters one from attempting to understand the methods used by astronomers in such problems as determining the sun's distance from the earth. This question, which enters the minds of nearly every one sooner or later, when shorn of technical detail, presents no great difficulties to the understanding, and requires less effort than directions concerning ordinary, every-day affairs which are read and assimilated as a matter of course.

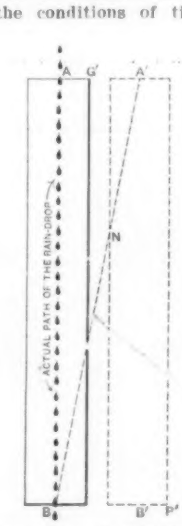


Fig. 1.—*AB* Represents the Raindrop Falling Vertically, Entering the Gas Pipe (held vertically) at *A* and Leaving at *B*

Now if during the time when the raindrop fell from *A* to *B*, the gas pipe was moved to the position *G' P'*, the raindrop would have struck the side at *N* since it entered the tube at *A*, and reached *B*, while the tube was moving to the right to the position *G' P'*.
The angle *B A B'* which is the aberration, is made greater or less by moving the tube a greater or less distance than *BB'* while the rain drop is falling through the distance *AB*.

In the realm of astronomy, as in other branches of science there are certain standards of measurement necessary for the problems which present themselves—the *base line* upon which the solar system, and from this the starry universe, rests. In *exact astronomy*, which deals with the distances, orbits and the forces which produce the motions of all the heavenly bodies, this unit distance is the number of miles from the earth to the sun or the radius of the earth's orbit.

The problem of measuring this distance has been attacked by astronomers for more than 200 years; in fact, previous to the year 400, by crude measurements depending on the unaided eye, the distance was estimated at something less than *five million* miles, or about one-twentieth its actual distance, and this value was accepted as the truth for more than twelve centuries.

There are numerous methods of determining this constant, differing widely in process and in principle. With modern instruments of precision the limits of error are comparatively small when the delicacy of the problem is considered, and the best efforts represent a difference of about *two hundred thousand miles* between the extreme limits; that is, the whole energy of two observers and assistants located at separate observatories for a period of a year or more may result in two values which differ from each other by this amount; and it is perhaps needless to say that of the thousands of efforts which have been made no two of them give exactly the same result.

The sun's distance, then, will never be known exactly, and astronomers will be forced to content themselves with a value which is so near the truth that the error is of no consequence. This is the case with all physical determinations or of any constant, dealing with natural philosophy. The City Engineer of New York can never tell exactly the length of a plot of ground on lower Broadway, where fractions of inches count for dollars. If he were to measure the same distance on two different days he would get two values, provided he measured to the thousandth of an inch.

By judiciously combining the various values that have been found for the sun's distance, there results one which is probably within *fifty thousand* miles of the true; and this value (92,928,700 miles) is so nearly true for all practical purposes, that any attempt to find a closer value simply emphasizes the fact that scientific man is never satisfied so long as there is uncertainty.

A method of finding this distance which appeals to the lay mind is by means of the *constant of aberration*. The principle is easily understood, and suggests some of the wonderful methods by which the astronomer overcomes obstacles when baffled in his attempts to strike directly at the problem. What could be more astounding to the ordinary mind than the idea of finding how far distant the sun is by not only ignoring the sun itself, but by taking the observations at night, when the sun is hidden from our sight!

Yet such is the case, and we shall soon see how this is accomplished. If a small piece of gas-pipe were held vertically during a thunder shower when the rain was falling straight downward, the drops of rain would pass through the tube without striking its inner surface, provided the person holding the tube remained stationary. If he started to walk, holding the tube vertically, the raindrops would strike the sides; and if he desired the drops to pass freely through the tube it must be inclined in the direction in which he is moving; and this inclination must be increased if his pace is increased. The same reason exists for holding one's umbrella in front if walking rapidly, providing the raindrops are falling vertically. By a simple principle of mechanics the angular amount of this inclination of the tube depends on the velocity of the raindrops and that of the man walking, and is called the aberration of the raindrops.

Now a ray of light, whether coming from a star or a candle flame, moves in a straight line with the enormous velocity of *one hundred and eighty-six thousand miles* per second; if a telescope is pointed

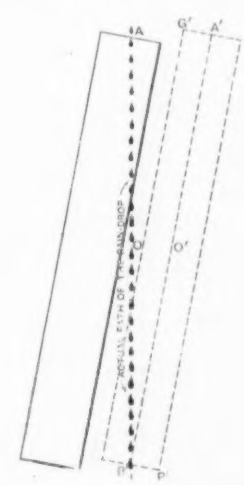


Fig. 2.—This Shows the Behavior of the Rain Drop Had the Tube in Fig. 1 Been Inclined in the Direction of Its Motion by an Amount Equal to the Aberration

The drop enters *A'* which was at *A* in the beginning and reaches *B'* thereby traversing the whole length of the tube through its center.
When the rain drop was at *O*, half way from *A* to *B'*, the center of the tube *O'* was at *O* also, since it had been moved just one-half its distance from *B* to *B'*.

on any star so that the rays of light pass through its center, then the telescope must be pushed ahead if the person holding it moves. On account of the earth's journey around the sun once a year, the telescope is being moved, and the astronomer determines from a series of observations extending through a longer or shorter period, usually lasting about a year, just how much the telescope has been inclined toward the east to cause the star to pass through its center, which is found to be about 20.49 seconds of arc—a very small fraction of a degree—and would correspond to a man walking at the rate of *three inches* per *minute* if the rain was falling at the rate of *fifty feet* per *second*.

Knowing the velocity of the rays of light, the rate of movement of the telescope necessary for this small angular deflection, which is the speed of the earth in its journey around the sun, is computed, which comes out about *eighteen and one-half miles* per second. If this be multiplied by the number of seconds in the year, the circumference of the earth's path around the sun is known, from which the determination of its radius, or the sun's distance, is an easy problem, since the earth's path is sensibly a circle.

The New Campanile in Venice

The Picturesque Plaza of St. Mark Resumes Its Wonted Appearance with the Completion of the Tower

By Charles A. Brassler

Very wisely, the style and form that were so effective in the old Campanile have been closely adhered to in the new tower, now about complete, and with the consecration of the new bells, donated by Pope Pius X., which were successfully cast on St. Mark's Day and have since been formally blessed and sounded to test their tone, the campanile will be perfectly replaced.

Even the architecturally beautiful Logetta of Sansovino has been reconstructed with infinite care and skill, much of the original artistic bronze work having been recovered from the ruins and restored with wonderful care and devotion, so that the new structure, except for the substantial solidity of construction called for in accordance with modern engineering methods and the newness of its appearance, is to all intents and purposes an exact counterpart of the old tower.

Although, at every stage, the most scrupulous care has been exercised, the work has progressed with notable rapidity. The new tower, which is forty feet square at the base and 350 feet high, including the pyramid-shaped top, is crowned, as was its predecessor, with an angel with outstretched wings. The old foundation, while found to be in perfect condition, was not regarded as wide enough to afford the desired stability to the new tower, and was widened considerably, as shown in one of our illustrations, while the area solidified by piling has also been very considerably increased. The cost of the new tower has been about 2,000,000 francs, made up of public subscriptions and a liberal grant from the State.

A brief history of the old tower and of the catastrophe that resulted in its destruction will be timely and interesting.

As the name indicates, the campanile is an Italian architectural feature, the word meaning literally a bell tower, the designation being usually applied to bell towers erected separately from the ecclesiastical edifice, of which they are actually an adjunct. Outside of Italy, the number of such towers is comparatively limited, so intimately is the idea associated with Italian architecture, particularly with the Italian renaissance style, to which it especially lends itself. There is a notably fine campanile at Seville, Spain, and the great tower on the building of the Metropolitan Life Insurance Company, New York, is of the campanile type, but it is to Italy that we must turn for characteristic specimens of this form of structure. The famous Leaning Tower at Pisa was erected for use as a campanile, although, owing to fear of the effects of the vibration on its stability, it has not, for some time, been put to practical use, while other famous campaniles are to be seen at Bologna, Padua, Ravenna and Cremona, and until July 14th, 1902, there stood, in the great square of St. Mark, adjoining the cathedral of that name, in Venice, one of the most imposing and strikingly effective campaniles in existence, which was the more conspicuous on account of the somewhat squat form of most of the surrounding structures and the heavy, rounded style of the domes and towers of the adjacent St. Mark's Church.

Originally intended as a watch tower, and part of the defenses of the city, at that time threatened by the Magyars, the campanile at Venice was of massive construction. Commenced in 888 by Pietro Tribuno, it was not until the reign of Domenico Morosini, about 300 years later, that it was completed, and even then it did not have the form in which it was known to modern times. The top was flat, or at most surmounted by a wooden belfry or spire. In 1417 a marble top was built, but it was not until 1590 that it was finished in the form in which we knew it, and it was a hundred years after that before the familiar golden angel—the guardian angel of Venice, as it was considered—was mounted on the top. When completed, its total height was 325 feet, and its estimated weight 20,000 tons.

MASS TO THE RIGHT IS THE OLD MASONRY. SURROUNDING THIS IS THE NEW CONCRETE EXTENSION OF THE FOUNDATIONS

VIEW OF THE CONSTRUCTION AT ONE OF THE ASCENT LANDINGS

THIS SHOWS THE ARCHES WHICH CARRY THE INCLINED WALK TO TOP OF TOWER

THE PARAPETS OF THE BELFRY

REBUILDING A FAMOUS VENETIAN TOWER

As already stated, the tower was originally surmounted by a wooden belfry or lantern, but several times, after being struck by lightning, this structure was destroyed by fire, and although the tower was on various occasions badly damaged by lightning, it was not until 1776 that it was equipped with a lightning conductor.

Built in the Italian renaissance style and somewhat severely plain, the great tower dominated all the surrounding structures. At first its chief use was as a watch tower, a watchman being constantly posted on the summit to look out for returning merchant ships or war galleys, which, from this lofty perch, could be seen many miles away, and their approach announced to the waiting messengers, by whom the news was circulated. But later it was used to hang the bells of St. Mark's Church, of which there were four, La Marangola, which was rung at dawn, to call the working people; La Sestamezzana, which rang to announce the opening of the official bureaus; La Trotteria, which called the councils to duty, and Del

Maleficio, which sounded the knell of those condemned to death. A fifth bell, which was brought from Candia and tolled only on Ascension Day, was subsequently hung in the tower.

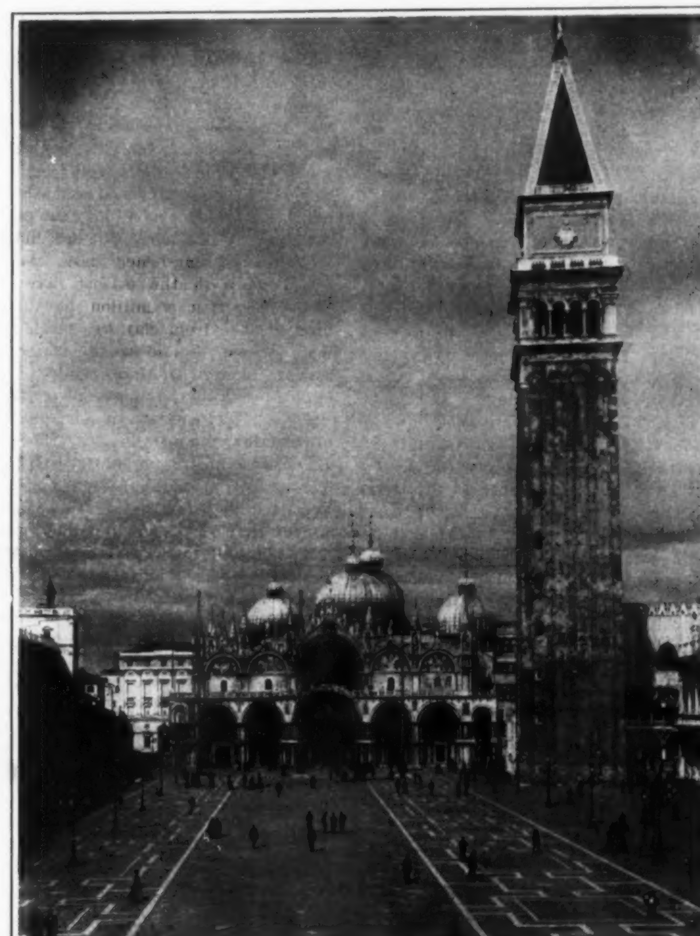
Another use to which the tower was put was by Gallileo, who used it, on several occasions in making his scientific observations, while high up, on one side, was a cage in which malefactors, guilty of certain crimes, were placed and starved to death. This barbarous practice was, however, subsequently abolished.

During the early part of its existence, the base of the tower was surrounded by shops, etc., mostly mean structures in which, on several occasions, fires occurred, that threatened the great tower. In 1540, however, the celebrated Jacopo Sansovino commenced the construction of the beautiful structure known as the Logetta de Sansovino, which it was originally intended to carry all around the base, but of which only one side was ever finished. Its erection caused the removal of the shops from this side, but they clung obstinately to the columns on the other sides; in fact, it was not until 1873 that the last of them was removed.

The Logetta was a two-story structure of elaborate design, and was originally the rendezvous for the nobles of the city. It was subsequently the headquarters of the guard. The front was adorned with handsome figures in bronze, four on the lower story, the work of Sansovino himself, representing Minerva, Apollo, Mercury and Peace. Under these statues were reliefs, portraying Tethys assisting Leander, the fall of Helle from the ram of Phryscus, etc.; three bas-reliefs in the attic story, representing Venice, as Justice, in the center, Jupiter on the left, to represent the dependent kingdom of Candia, and Venus on the right, representing the vassal kingdom of Cyprus. The figures were the work of Tiziano Mini and Girolamo Lombardo. In 1750, the bronze gates, superb pieces of work, ranking with the choicest specimens of the plastic art in metal, were completed by Antonio Gai.

In 1878 a competent Italian architect, Luigi Vendraseo, after careful observations, realized that the tower was no longer stable, and warned the authorities of its condition. For fifteen years he continued, at intervals, to call the attention of the officials to the threatening condition of affairs, until, tired of his importunities, he was banished to another city, but on account of his age and infirmities he refused to go, and was deprived of his professional rank. At about this time some repairs to the roof of the Logetta became necessary, and the contractor cut deeply into the walls of the campanile. This led to the reopening of a fissure, caused by lightning some years before, and only unskillfully repaired. The attention of Vendraseo was called to the state of the structure, and he warned the authorities, on July 13th, 1902, that it would probably not last longer than twenty-four hours. His warning proved only too true. At 9 o'clock on the morning of July 14th the great tower collapsed into a heap of rubbish, some eighty feet high, and extending to the very walls of St. Mark's Cathedral, on the summit of the pile being one of the great bells, the only one of the peal to escape destruction.

The fall of the tower was described as the result of disintegration, owing to old age and decay, but the consensus of opinion is that the disaster might have been averted had the Government heeded the warnings of the experts and taken proper steps to strengthen the structure. As it was, it fell almost without a sound, and except that the north corner of the adjoining Palace Library was crushed in, caused no damage to surrounding structures, nor was a single living creature killed or injured by the fall. The golden angel that stood on the apex of the tower escaped destruction, and was found, practically uninjured, in the circle of the doorway of the great cathedral, as though it had sought safety within its sacred portals. The superstitious Venetians say it had flown home, and a place was reserved for it in the cathedral, to commemorate the event. The angel had occupied its commanding position since 1822, when it was set up to replace the one installed more than 200 years before.



ST. MARK'S SQUARE AND CHURCH AND THE OLD CAMPANILE BEFORE ITS FALL

Careful examination of the debris by experts and engineers revealed the fact that the mortar had lost its cohesive value, was in fact nothing but dry, white dust, so that when the deep cut was made in the wall there was nothing to prevent the building, deprived of support at this point, from crumbling to pieces. This indeed seems to have been its fate, eyewitnesses describing the collapse as a gradual subsidence of the entire structure into a heap of debris, the golden angel on its summit being visible, descending in a vertical position, until hidden by the cloud of white dust. The Logetta, of course, suffered badly, a number of Sansovino's superb bronzes, including the statues of Minerva, Apollo, Mercury and Peace, and those of several Venetian nobles, together with the magnificent bronze gates, suffering severe damage. The rubbish, however, was carefully sorted over, and every particle of bronze recovered preserved, so that it was still possible to reconstruct some of the metal decorations for the new tower. In the damaged portion of the Palace Library, a fine picture by Paul Veronese was destroyed.

The bricks of which the tower was built were found, in large part, whole, sound, clean, and as good as when laid. Some of them were hundreds of years old, having been taken from Roman ruins at Aguilea, and dating from the first century before Christ. It was proposed to use a quantity of these bricks for the erection of a pyramid, thirty feet high, in the public gardens of the city, as a memorial of the old campanile, so long one of Venice's glories.

It was at first thought that the disaster might have been due to a defect in the foundation, in view of the unstable character of the soil on which the city

OLD BASE OF CAMPANILE FREED FROM THE TOWER DÉBRIS

REINFORCED CONCRETE FLOOR OVER THE BELL CHAMBER

REBUILDING A FAMOUS VENETIAN TOWER

is built, but on examination this was found not to have been the case. The tower rested on a foundation that had a base sixteen feet and six inches deep, built of twelve courses of different kinds of stone laid on a platform of two layers of oak beams crossed and resting on a bed of clay, into which piles of white poplar had been closely and deeply driven. The collapse evidently was not due to any failure of the foundation. The bungling manner in which, in making the repairs to the roof of the Logetta, the workmen reopened the old fissure, which dated from 1513 and had never been scientifically repaired, was doubtless the immediate cause of the disaster, which had been imminent, as the architect predicted, for years before it occurred. The indifference of the authorities, when their attention was called to the impending disaster, is astounding. Some workmen had reared a ladder against the wall of the tower on the morning of its fall, and when climbing it noticed the crack and the rapidity with which it was spreading; they had barely time to scramble down to a place of safety before the tower collapsed. That no one was killed or injured was due in no wise to precautions taken by the officials, but to the fact that so few people were about, and that those who were in the neighborhood saw the unmistakable signs of the approaching disaster and got out of the way.

The destruction of this structure was not only an irreparable archæological loss to the city of Venice and the world at large, but the absence of the tower left a vacancy in the architectural effect of the group of buildings surrounding St. Mark's Square that destroyed the scenic beauty of the whole. This the authorities fully realized, and to fill the void they have now erected a new campanile, on the site of the old one, using its foundations, strengthened and extended according to the requirements of modern engineering science, and following as closely as possible the lines of the old bell tower. The accompanying illustrations will give a fair idea of the measure of success that has rewarded their efforts, and, while the building will not be the old campanile, that for so many years looked over the stirring events that marked the rise and progress of the Venetian republic, it is certainly a handsome and imposing edifice, which entirely restores, with its cloud-piercing altitude, the harmonious equilibrium of this most attractive portion of the picturesque city. Doubtless, too, it is free from the faults or defects, of whatever their nature, in the choice of material and method of erection of the old tower, that led to its disastrous failure, at an age when so many much older buildings are standing, firm and solid as the everlasting hills.

The dust had hardly settled after the fall of the old tower, a little over eight years ago, when its early replacement was suggested, it being realized that the general effect of the square was seriously marred by its absence. In removing the debris, which was shortly commenced, every fragment of the metal work or stone carvings, of the elaborate Logetta de Sansovino especially, was preserved with conscientious care, with a view to the restoration of both tower and logetta in their original form. The foundation, when laid bare, was subjected to the most rigorous examination by engineering experts, and it was finally decided to widen it to a very considerable extent, the new work being of massive masonry, resting on innumerable piles, driven into the underlying clay. On this greatly strengthened base, the new campanile was reared, with the utmost care; the bricks, of which more than a million have been used, being specially made from clay twice mixed, to insure uniformity of texture, and each brick being twelve inches long, six inches wide and three inches deep. As Signor Edoardo Dr. Piacentini, the chief superintendent, informs the writer, it was found, shortly after the work was commenced, that owing to the presence of certain salts in the clay, there was likely to be an efflorescence that would greatly disfigure the tower. These salts, it was subsequently discovered, could be extracted by prolonged steeping and thorough washing of the bricks, and not only was this done afterward, but all the work already done with the objectionable bricks was torn down and the bricks subjected to the same treatment. Huge pans are provided in which this is effected. The main shaft, which is quadrangular, and tapers imperceptibly toward the summit, was finished in December, 1910, and consists of an inner and an outer shaft, the walls of the latter being six feet in thickness. Between the inner and outer shafts, the inclined plane, which serves in place of a staircase to reach the belfry, is disposed, its construction, of reinforced concrete, being shown in one of the accompanying illustrations. The reinforcement binds the inner and outer shafts together, the pilasters, at the angles of the inner shaft, being of similar construction, and entering into the system. This makes the huge tower practically an immense monolith, and should it ever decide to fall again, it will have to come down as a solid mass, in place of crumbling to pieces as formerly. Light is furnished by thirty-six windows to the inclined plane.

The tower was built, from the ground up, without scaffolding, an ingenious sliding platform, that was contrived to rise as the structure progressed upward, being used by the masons, until the belfry platform was reached. The lantern and belfry, with the dado of the spire and the spire itself, required a separate scaffold. A heavy wire netting under the platform prevented the fall of anything to the ground.

The reconstruction of the tower had progressed, by June 22nd, 1910, far enough to permit of the replacement of the bells in the belfry. The smallest bell, the Trotteria, was first raised into position by means of the electric hoisting apparatus. This bell weighs but ten hundredweight, and rings daily for half an hour after noon. All, including the great bell weighing thirty-six hundredweight, were successfully raised and are now ready for ringing.

The work of reconstructing the beautiful Logetta de Sansovino has also made excellent progress. With greatest care the fragments of delicately carved stone have been reunited, some idea of the labor this involved being realized when it is stated that of three marble columns, forming part of the façade fronting St. Mark's Cathedral, one was reconstructed from thirteen and another from thirty-two pieces, while the third had to be replaced, suitable marble being brought from an ancient villa near Rome for this purpose. The care displayed in the reconstruction is further revealed in the manner in which the angel is supported on the summit of the tower. The pedestal on which it rests is kept in place by a pendulum that swings free in the spire, so that it will yield without unduly straining the structure.

While the authorities may fairly be criticised for allowing the old tower to lapse into the condition that resulted in its collapse in July, 1902, they are certainly entitled to no small credit for the expedition with which the great building has been replaced, the artistic character of the new structure, and the enduring manner in which the work has been carried out. Apart from the interest attaching to the antiquity of the old tower, it is indeed a question whether Venice has not profited by the disaster of eight years ago and the tardiness in protecting or reinforcing the old tower—if, indeed, this was possible, in the light of investigations as to the cause of its fall—will be overlooked when the bells peal from the new tower.

The Principles of Original Research

Prof. Sedgwick Minot's Views

Since pure science has been pre-eminent in the past not only in furnishing useful knowledge, but also as a chief foundation of human progress, and is likely long to continue equally pre-eminent, it is well worth while to study the general principles by which original research is guided. An analysis of the situation forms one of the topics discussed by Prof. Sedgwick Minot in his recent address before the American Association for the Advancement of Science. We quote him in his own words:

"No previous definite study of these principles is known to me, although I have searched not a little to find one. All that I have been able to discover are treatises on logic, the reading of which, most active investigators would, I fear, find tedious and unprofitable rather than helpful and inspiring. We have too many real difficulties to quite enjoy wading through the artificial morass of pedantries, in which logicians by profession imbed their significant truths. The stricture is severe, but not too severe even for so sound and valuable a work as Jevons's 'Principles of Science.' It must be doubted very seriously whether the study of logic is really essential for the right training of an investigator. While it goes without saying that logical thinking is indispensable in science, neither may it be overlooked that thinking is a complicated physiological function, which is brought to efficiency by practice, and that training by actual use is the one indispensable means of disciplining and developing the function. Playing the violin is a complicated physiological function, but it is not thought necessary that the violinist should study the anatomy of the muscles and nerves of the hand and arm. He perfects himself by practice. Anatomical knowledge might enable him to understand why he can make certain motions and can not make others. Our analogy limps, perhaps, but is a real analogy, for practice in right thinking creates the necessary habit of being logical, and ability to describe the mental processes in the language of logicians is an accomplishment which few even of the greater scientific discoverers possess.

"It is my belief that the logical work of scientific men is usually well done, and is the part of their work which is least faulty. The difficulties and the majority of failures are due, it seems to me, to two chief causes, the first, inadequate determination of the premises, the second, exaggerated confidence in the conclusions. If I am right, the method of science is the result of the effort to get rid of these two causes of error.

"We must recognize in starting that the expression, 'the method of science,' means more than 'logic,' being far more comprehensive when rightly defined. We can not alter the fundamental conditions of knowledge, for we are still unable to add new senses or improve the brain—although eugenics dreams of a future with such possibilities—nor can we change the nature of the phenomena. The same fundamental resources are available for daily life and for science. We must be clear in our minds on this point, in order to comprehend that the fundamental distinction of the scientific mind is its accuracy. As I have said on another occasion, 'there is nothing to distinguish the scientific method from the methods of every-day life except its precision. It is not a difference in kind or quality, but a quantitative difference, which marks the work of the true scientist and gives it its validity.' Such being the case, a broad examination of the method of science reduces itself to the study of the general principles of securing accuracy.

"If you will examine frankly your own opinions and those of your acquaintance you will, it may be presumed, quickly acknowledge that many, perhaps most, of the opinions are not of scientific accuracy. On the contrary, they are, to a large extent, mental habits and the result of the summation and averaging of impressions. I, for example, know a generous man, but can give very little of the evidence on which my opinion is based. I know a seacoast on which a fog occurs in summer very frequently, yet I cannot state how often the fog occurs nor just when I have observed it. At sundry times I have received an impression, in one case of the man's generosity, in the other of fog. The exact data cannot be recalled, but the impression on my mind has been fixed by repetition. The evidence is lost, but the conclusions persist and are accepted by me as correct. For my practical needs they are sufficient. We get along in ordinary life satisfactorily enough with opinions thus formed by summation. Most human opinions, even when they are merely imitative, originate in this way, and are correspondingly unreliable. If we seek to explain the fallibility of ordinary opinions and testimony, must we not attribute it to the absence of the detailed evidence and the consequent impossibility of verifying the testimony?

"We are thus led to recognize the preservation of the evidence as the fundamental characteristic of scientific work, by which it differs radically from the practice of ordinary life. I venture accordingly to define the method of science as *the art of making durable trustworthy records of natural phenomena.* The definition may seem at first narrow and insufficient, but I hope to convince you that it is so comprehensive as to be not only adequate, but also almost complete.

"All science is constructed out of the personal knowledge of individual men. Science is merely the collated record of what single individuals have discovered. Accordingly, we must consider the way in which the individual knowledges are recorded and collated. The process begins, of course, with the publication of the special scientific memoir in which the investigator records his original observations and makes known his conclusions. It is interesting to note that our present standards for original memoirs have developed gradually. In Harvey's essay on the circulation of the blood, published in 1628, there are no precise data as to his observations. The author does not think it necessary to specify how he has laid bare the heart or how often he has repeated his observations. His descriptions of the beating heart are vividly realistic. He writes with conviction and authority. The reader is compelled to believe him. Harvey, however, does not provide information to

facilitate repetition of his work—he offers little aid toward the verification of his results. Francesca Redi, the founder of experimental biology, published his 'Generation of Insects' in 1660. His experiments proved that insects are not spontaneously generated in putrefying meat. His conclusion is sound, but he does not give more than a general account of the actual experiments. A century later Spallanzani established the modern standard, and in his works we find the details as to his evidence put down with scrupulous care, for example, in his paper on the circulation (1773) the individual experiments are exactly described. But Spallanzani in this, as in other respects, was far in advance of his time.

"In a contemporary article we expect a presentation of all the data necessary to render subsequent verification by other observers possible. We further expect clear information as to the amount of material on which the observations were made, or the number of experiments on which the work is based. In other words, a modern investigator will hardly receive consideration for his researches unless he furnishes every aid he can to facilitate criticising and testing his results. This severe standard has been only gradually evolved, but is now stringently enforced in all departments of science, and is the response in our practice to our need of eliminating the purely personal factor. It would be advantageous if scientific authors generally viewed the obligation of providing for verification as an even more serious duty than it is esteemed at present. It might, indeed, be a wholesome practice to demand that every scientific article should contain a special section or paragraph on the means of verifying the result, for verification by *Fachgenossen* is second in importance only to discovery in the progress of science.

"The conditions of scientific progress have changed greatly though very gradually. Two hundred years ago the number of active investigators was small. This year there are at least ten thousand men of substantial ability carrying on original researches, consequently each theme is being worked at by several men, and the final outcome is the consequence of collaboration, which is none the less actual and effectual because it is unorganized, and is usually not formally designated as collaboration. For example, our present knowledge of the complex and very varied processes of cell-division has been constructed not merely by successive accumulations, but also by incessant debate and repeated mutual criticism. Within a generation the modern science of bacteriology has been created. Within a few years radiology, the wonders of which still thrill us, has suddenly come into existence. Both great achievements are the results of both the original observations and also the constant mutual discussions of a number of scientific men.

"These conditions have rendered great men somewhat less important than formerly. Science grows by the accretion of ideas. Now, a great man has, let us say, twelve new ideas, where a man of ability has one. If science gets twelve new ideas it matters little whether they come from one man or from twelve. To a certain extent numbers make a substitute for genius—but nothing probably will ever replace that type of great genius to which we owe most, the man who has a great thought, which no one has ever conceived before.

"We recognize in the present methods of recording and collating scientific discoveries many adaptations which are due, it seems to me, essentially to the mere increase in the number of workers. But though the methods are modified the essential steps are the same: First, the record of the individual personal knowledge; second, the conversion of the personal knowledge by verification and collation into valid impersonal knowledge; third, the systematic co-ordination and condensation of the conclusions.

"Many definitions of science have been given, and did time permit it might be profitable to quote some of them; but is it not sufficient to define science as *knowledge which has acquired impersonal validity?*"

An Important Report on Sewage Disposal Investigations

The Studies of the Philadelphia Bureau of Surveys

A valuable contribution to the literature of sewage purification has been made by the Bureau of Surveys of the Department of Public Works, Philadelphia, Pa., in its partial report upon the comprehensive plan for the collection, purification and disposal of the sewage of the entire city. The information, which has just been made available for publication, is based upon such extensive and careful research work that it will serve as a much needed and welcome addition to the existing data upon the treatment of sewage of American cities, which are admittedly far too meager in proportion to the growing importance of the subject in this country.

Philadelphia is required by statute to submit to the State Department of Health on or before January 1st, 1912, a comprehensive plan for the collection and disposal of sewage of the various drainage districts of the city. A plan of such magnitude demanded very complete preliminary investigations to determine upon the method of purification best suited to local conditions and on July 20th, 1907, the necessary authorization for conducting experimental work, with which the present report deals, was granted. During the following year Mr. George R. Stearns, director of the Department of Public Works, and Mr. George S. Webster, chief engineer of the Bureau of Surveys, visited the sewage disposal works of the principal cities of Europe and also inspected a large number of plants in this country. Upon their return Dr. Rudolph Hering was engaged in an advisory capacity, and a division of the Bureau of Surveys, known as the Sewage Disposal Division, was organized under the supervision of Mr. George E. Datesman, principal assistant engineer. A sewage testing station was established near the Spring Garden pumping station of the Bureau of Water, and experimental work was begun on March 23rd, 1909, under the immediate direction of Mr. W. L. Stevenson, assistant engineer in charge, and continued until May 15th, 1910.

The scope of the experimental work at the testing station was wide and included investigations of fine-mesh screenings, sedimentation in horizontal-flow tanks and in a vertical-flow Imhoff tank, slate contact beds of the Dibdin type, double contact beds, sprinkling filters, Hamburg and intermittent sand filters, disinfection, dilution and sludge. The report contains 204 printed pages in addition to a great many drawings, diagrams and curves, and no attempt will be made at this writing to give anything but an outline of the general conclusions which were reached. The report is intended as a progress report; some of its conclusions are summarized in the following paragraphs.

Fine screening, through metal cloth containing 35 meshes per inch, removed one-third of the suspended matter in the crude sewage as applied, prevented the formation of scum in subsequent sedimentation tanks and prevented the clogging of the nozzle orifices on the sprinkling filter beds.

Experiments on horizontal flow sedimentation showed that three and one-half hours' nominal flow through a baffled tank removed two-thirds of the suspended solids in the crude sewage and that increased storage did not produce a proportionate improvement in the efficiency of the tank. Between periods of three and one-half to six hours' flow the influent was not deoxidized nor rendered offensive when sprayed upon sprinkling filters. To prevent septic action the tanks required sludging and washing out every six weeks.

In the studies of vertical-flow sedimentation the Imhoff tank was used, and by the substantial separation of the sewage flow from the digesting sludge it was found possible to keep the sewage fresh and eliminate offensive odors either in the effluent, the sludge or the gas developed.

In operating the slate contact bed it was found that the best results were accomplished when the bed was filled twice a day or at a rate of 2,000,000 gallons per acre daily. Crude sewage applied deposited three-fourths of the suspended solids. The conclusion was reached that where slates are not a waste product the construction of beds of this material would be costly.

The sprinkling filters were found to produce the best results with fixed sprinkler nozzles when the film of sewage was made to travel constantly back and forth over the media without a resting period. The superiority of a uniform over an irregular rate of operation was established. The maximum rate obtained with exposed filters was 2,500,000 gallons per acre per day, but in winter the stability of the effluent deteriorated. With a filter protected from the weather and receiving fine screened and settled sewage uniformly distributed over its surface the maximum rate was 3,100,000,000 gallons per acre per day. The effluent was found to be stable practically all of the time.

In studying various kinds of filtering media it was found that trap and gravel maintained their initial size, while limestone and slag disintegrated to a slight extent. The smooth surface of the gravel stone was not as well adapted to the formation of a bacterial jelly as rougher media and the extreme roughness of slag caused it to retain the deposited solid, so that clogging soon ruined the bed. In the uncovered filters, operating at 2,500,000 gallons per acre daily, the best results were obtained with trap media from 1 to 3 inches in size. Under the more favorable conditions of fine screens and settled sewage distributed at a rate of 3,100,000 gallons per acre per day media ¾ to 1½-inch size produced an excellent effluent.

Filters of less depth than 6 feet were not satisfactory, but with depths greater than 6 feet a satisfactory effluent was obtained, operating at rates between 2,500,000 and 3,000,000 gallons per acre daily. Additional depth over 6½ feet did not seem to be economical.

At rates between 2,500,000 and 3,000,000 gallons per acre per day media composed of stones uniform in size completely unloaded the solids stored in the interstices, whereas stones of great diversity in size became badly clogged, but did not unload. Ice caused no trouble in operation.

Fungus growths on the filter surface were completely removed by an application of calcium hypochlorite dissolved in water without interefering with the biological action of the bed.

It was found impossible to operate the Hamburg and the intermittent sand filters at rates high enough to be economical for the conditions in Philadelphia.

Crude sewage, passed through a fine-mesh screen or satisfactorily settled to remove solids larger than about 1/25 inch and disinfected with calcium hypochlorite to yield six parts per million of available chlorine was added to river water in proportions up to one to ten, and its purification accomplished without offense to sight or smell, or without depleting the dissolved oxygen of the river water below fifty per cent saturation.

In the studies of sludge it was found that horizontal flow in sedimentation tanks produced sludge, 88 per cent moisture, at an average rate of 5 cubic yards per 1,000,000 gallons. An Emscher tank with 4½-foot vertical flow produced sludge, 82.6 per cent moisture, at an average rate of 0.9 cubic yard per 1,000,000 gallons of sewage. The placing of sludge from a sedimentation tank in a water-tight uncovered tank for digestion did not prove successful. In the sludge bed tests fine sand or sawdust over a coarse drainage floor proved more efficient for reducing moisture in the sludge than a plain earth lagoon. Wet sludge from a sedimentation tank applied 6 inches deep in winter weather under cover dried to a consistency fit to remove in six days, and under the same conditions but not under cover in twelve days. Based upon small size tests in winter weather Imhoff tank sludge, 12 inches deep upon a sand bed, dried to a consistency fit to remove in twelve days during freezing weather. When equal weights of rice coal and wet sludge were mixed and placed on sludge beds the mixture was fit to remove in one day and was successfully burned.—*Engineering Record.*

Tool Hardening by Gas

The use of the gas furnace for forging, tempering and hardening steel is spreading among the workshops where cutlery and tools are made. The old "hearths" are disappearing, replaced by small, clean gas furnaces, which are not only economical in space and cost of running, and comparatively clean and neat, but furnish a uniform temperature of any desired degree, thus avoiding damage to the steel through "burning," or irregularity of temperature. The working of the furnace is economical, because the gas can be cut off the moment the operation is finished.

English Lithographic Pencils

Melt, in a metal vessel, 30 parts of wax, 25 parts of talcum, 20 parts of soap, 15 parts of shellac and 6 parts of lamp black, mixing thoroughly by stirring. The melted mass is then quickly heated so intensely that it ignites. It is alowed to burn for a time, then take a sample in a spoon, and cover the vessel with a tight-fitting lid, so that the fire is immediaely extinguished. From the sample, a pencil is formed, which when tested on the stone must display the characteristics of a good lithographic pencil. In case the mass is not sufficiently elastic, it must be again ignited and allowed to burn for a time. When the mass has at length attained the desired consistency it is poured out on a marble slab, and rolled into sticks of about 2¾ to 3 inches long and of the thickness of a thin pocket book lead pencil.

Some Recent Types of Aeroplanes

The Voisin Biplane; the R. E. P. Monoplane; the Breguet Biplane; the Nieuport Monoplane

The accompanying illustrations and descriptions which are reproduced from *Flight*, explain the essential features of four of the most important types of aeroplanes of recent construction. The details of the machines can be gathered from the specifications given below.

THE VOISIN BIPLANE.

Constructed in France by Voisin Frères (Charles and Gabriel Voisin). The first European biplane of real success. Elevator incorporated in tail. No forward elevator. Framework of steel tube. Fabric is Continental aeroplane material. A type with conventional wooden framework is still constructed. Holder of the world's biplane speed record, made by Bunau-Varilla at Rheims (1910).

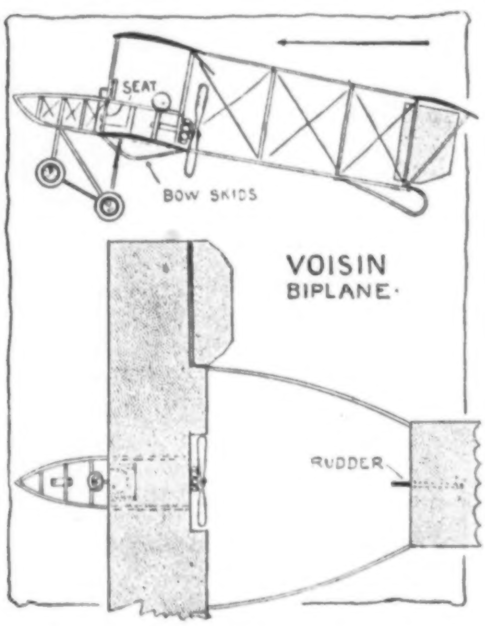
General Dimensions.—Length over all (steel type), 34½ feet; (wooden type) 34 feet; width (steel type), 36 feet; (wooden type) 33 feet. Width of main planes (both types), 6½ feet.

Seating Capacity.—(Steel type) two seats placed side by side and with dual control; (wooden type) single seater, seats placed in front of main planes in both types.

Engine.—60 horse-power 8-cylinder V-type water-cooled E. N. V., or 50 horse-power 7-cylinder rotary air-cooled Gnome, or according to choice.

Propeller.—Voisin two-bladed, of steel; variable pitch. Situated behind main planes.

Chassis.—Two wheels; no skids; small wheel placed forward about 3 feet from the ground to take initial shock of bad landing.



Tail.—Monoplane tail with elevator hinged to trailing edge. Single rudder placed centrally below tail plane.

Lateral Stability.—By large ailerons fitted to the trailing edge of the upper main plane.

Weight.—Complete, with motor (60 horse-power E. N. V.), 814 pounds.

Speed.—50 to 56 miles an hour.

System of Control.—By a wheel at the end of a horizontal shaft and moving in a sleeve; pulling the wheel elevates the machine, pushing depresses the elevator; rotating the wheel in either direction steers the aeroplane as an automobile. Two pedals in front of the pilot actuate the ailerons for the maintenance of lateral stability, the right pedal depressing the left aileron, and *vice versa*.

Price.—(Steel type) with 60 horse-power E. N. V., 25,500 francs ($5,100); with 50 horse-power Gnome, 28,000 francs ($5,600); without engine or propeller, 14,000 francs ($2,800). (Wooden type) with 60 horse-power E. N. V., 23,500 francs ($4,700); with 50 horse-power Gnome, 26,000 francs ($5,200); and with 55 horse-power Antoinette, 25,000 francs ($5,000).

THE R. E. P. MONOPLANE.

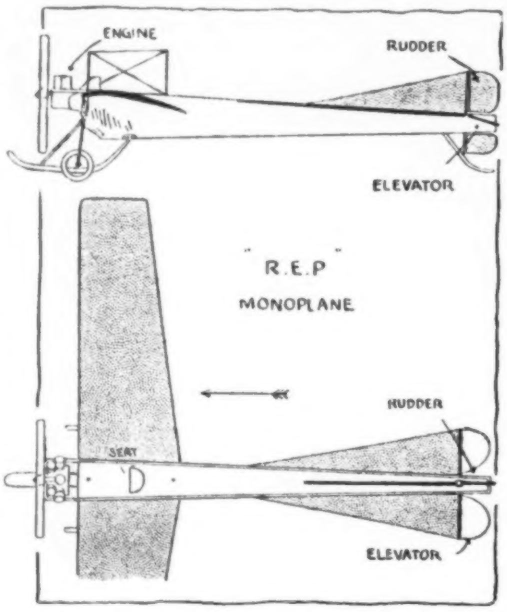
A French-built monoplane. Framework of steel tubes covered with Continental aeroplane fabric colored red. Planes double-surfaced throughout. M. Robert Esnault-Pelterie, the designer and constructor of both the aeroplane and the engine bearing his initials, though yet but a little over 30, was one of the earliest successful pioneers of mechanical flight.

General Dimensions.—Length over all, 31 feet; width, 42 feet; height, 10 feet; length of each wing, 20.7 feet; breadth of each wing at widest point, 8.2 feet; total bearing surface, 270 square feet.

Seating Capacity.—One or two seats.

Engine.—50-60 horse-power 5-cylinder semi-radial R. E. P. Normal revolutions, 1,000.

Propeller.—Normal. Two-bladed in wood, 8.5 feet diameter.



Wheels and Skids.—Two wheels with single central hollow wooden skid. Whole chassis carefully sprung.

Tail.—Non-lifting tail plane with elevator hinged to trailing edge, divided to admit of the rudder working in the center. The rudder is similarly divided to allow for the working of the elevator.

Lateral Stability.—By flexing the trailing edges of the main planes.

Weight.—With 50-60 horse-power R. E. P. motor, 1,056 pounds.

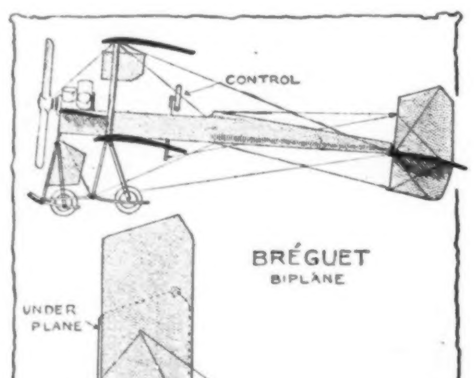
Speed.—56 miles an hour.

System of Control.—By means of two levers situated on opposite sides of the pilot. The left-hand lever, when moved backward, elevates the machine, and *vice versa*. A sideways movement to the left depresses the right wing, and to the right the left wing. The right-hand lever, if moved to the right, steers the machine in that direction, and the opposite movement steers to the left.

Price.—With 50-60 horse-power R. E. P. engine, 29,000 francs ($5,800). No other engine is fitted, and the aeroplane is not supplied without a motor.

THE BRÉGUET BIPLANE.

Constructed by Louis Bréguet at Douai. Fuselage and framework of steel and wood. Planes double-surfaced throughout. The main planes are connected by four stanchions placed a short distance back from the leading edge. Well known for its weight-lifting powers. On one occasion M. Bréguet carried five passengers beside himself, the total weight of the six persons being 924 pounds. Beside the one described, a racing model with only 280 square feet bearing surface, and fitted with a higher-powered engine, is also made.



General Dimensions.—Bearing surface, 280 square feet; length overall, 30.2 feet; span of upper main plane, 43.3 feet; of lower main plane, 32.5 feet. Wings of normal type are 5.6 feet broad.

Seating Capacity.—Two seats, placed one behind the other.

Engine.—50-60 horse-power 5-cylinder semi-radial R. E. P. motor. Normal revolutions, 1,000. Any motor fitted.

Propeller.—Bréguet, of two blades. Diameter, 9.5 feet. Geared down, variable pitch. Normal revolutions, 600.

Chassis.—Three wheels, one centrally in front of other two (which are each double); short skids in front of each wheel; front wheel is steerable by means of ordinary control wheel. The entire aeroplane is suspended on these three wheels, there being neither skid nor wheel under the tail.

Tail.—Cruciform monoplane tail, mounted on universal joint.

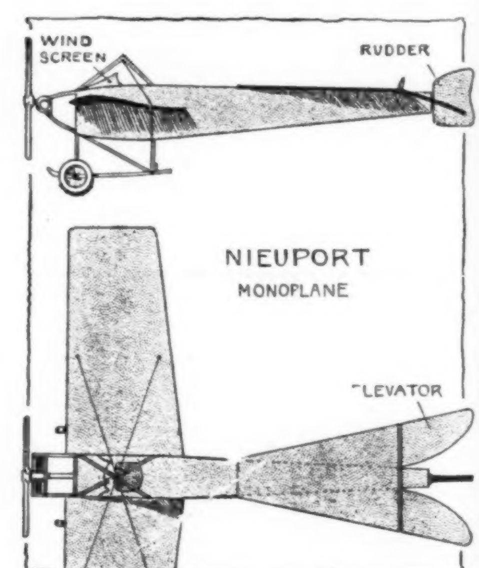
Lateral Stability.—By the flexing of the trailing edges of the main planes.

Weight.—About 1,045 pounds, complete, with motor.

Speed.—53 miles an hour.

System of Control.—By a wheel placed on a lever. Rotation of the wheel steers the machine. Backward and forward movements of the entire column elevate and depress the aeroplane, and a sideways movement to the right or left depresses the opposite wing in either case.

Price.—With 50-60 horse-power R. E. P. motor, 30,000 francs ($6,000).



THE NIEUPORT MONOPLANE.

French-built monoplane. Made its first appearance at the Rheims meeting, 1910. Planes double-surfaced throughout. Entire fuselage is covered in with fabric. One of the lightest and most efficient aeroplanes on the market.

General Dimensions.—Bearing surface, 160 square feet; length over all, 24.6 feet; span, 27.6 feet.

Seating Capacity.—One or two seats.

Engine.—20-25 horse-power 2-cylinder horizontal opposed air-cooled Darracq motor. Normal revolutions, 1,200. The 5-cylinder 40 horse-power Anzani or the 50 horsepower Gnome can be fitted at an increased cost, as shown below.

Propeller.—Chauvière Intégrale. Diameter 6.6 feet. Pitch, 3.94 feet. Effective revolutions, 1,200.

Wheels and Skids.—Two wheels connected by a flexible leaf spring. A single skid is placed centrally, curving forward and upward.

Tail.—Non-lifting fin extending to elevator, which is in two parts to allow single rudder placed centrally to work freely.

Weight.—Complete, with engine, 550 pounds.

Lateral Stability.—Maintained by flexing the trailing edges of the wings. The wings are connected by a patented arrangement by which one wing automatically alters the curvature of the other wing when under undue pressure, thereby maintaining stability to some degree.

Speed.—46½ miles an hour.

System of Control.—The flexing of the wings for the maintenance of lateral stability is performed by two independent pedals, each controlling one wing. A wheel control actuates the rudder, and the backward and forward movement of a lever works the elevator.

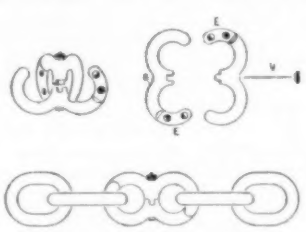
Price.—Two-seater, with Darracq 20 horse-power motor, 18,000 francs ($3,600). Two-seater, 40 horse-power 5-cylinder Anzani, 22,000 francs ($4,400). One-seater, 50 horse-power Gnome, 24,000 francs ($4,800). Two-seater, 50 horse-power Gnome, 26,000 francs ($5,200). Any engine can be fitted if required.

Some Interesting New Inventions*

Useful Little Things

JOINTED CHAIN LINK.

It not infrequently happens that the unforseen giving way of a chain at an awkward moment places us in a serious predicament, if at the time there are no immediate facilities for forging a new link to repair the damage. The invention of which our illustration gives a view seems calculated to be of great service, not only in such cases as this, but indeed under any circumstances, by affording a ready means for quickly introducing at least a temporary link in place of the

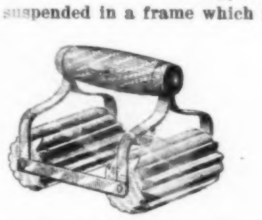


JOINTED CHAIN LINK

defective one. The device is very simple, consisting of two half links *EE*, expanded at their central portion into a socket *O*, through which can be extended a threaded rod *V*. In this way the two halves of the link are pivoted together, and by twisting them into the position shown in the first drawing of our diagram they are adapted to receive into their two loops the two end links where the chain has been severed. The tension of the chain then automatically closes the opened link, which is preferably further secured together by suitable means.

LAUNDRY IMPLEMENT.

In the ordinary process of washing, the linen is subjected to a rather severe rubbing treatment, which is not calculated to prolong the life of the material. An invention calculated to obviate this disadvantage consists, as shown in the annexed drawing, of two ribbed rubber rollers suspended in a frame which is provided



LAUNDRY IMPLEMENT

with a handle for convenient manipulation. The action hardly requires explanation. The linen, soaked in soap suds, is laid upon an inclined board, and the instrument is then passed to and fro over the article like a brush. While this operation thoroughly works the soap suds into the material, and assists them in their detergent action, it is free from the defects inherent in the action of a brush.

A TOY AEROPLANE DESTROYER.

We have all heard the discussion which has been going on with regard to the possibilities and limitations of the aeroplane as an instrument of war. If it is difficult, as some have contended, to hurl upon an enemy, with any accuracy of aim, missiles and ex-

A TOY AEROPLANE DESTROYER

plosives from an aeroplane hovering above, still more problematical must it be to reach the aeroplane from the earth below and inflict injury upon it by means of any of the ordinary ordnances of our artillery. These circumstances have inspired the inventor of the little toy shown in the annexed figure. Rising up from a base board a vertical pillar supports at its top two radial arms from which are suspended at opposite ends a model of a flying machine and of a bird. A clockwork mechanism keeps the device rotating around the central pillar, and a toy gun can be aimed at the figures flying past it, and a good deal of amusement is derived from one's frequently unsuccessful efforts to hit the models as they fly past the gun.

A WIND-PROOF UMBRELLA.

Everyone has at some period or other experienced the somewhat ludicrous and often very annoying accident of having his umbrella turned inside out and perhaps damaged on a stormy day. Mr. Kramer of Paris has exercised his ingenuity to invent a device which should place those seeking shelter under that time-honored implement beyond the reach of such an embarrassing and humiliating accident.

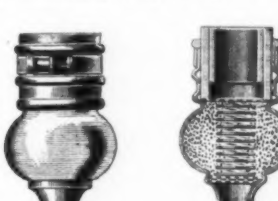
The nature of the device is shown in our illustration. It is extremely simple, its essential feature being a double stop, as indicated by *M* and *N* in the small annexed detail drawing, the upper tooth *N* serving to hold back the usual system of ribs *D* in case the wind catches the umbrella from its concave side, tending to injure it. The principle of this device, the mere introduction of a second stop, in addition to the usual one whose function is, of course, merely to hold

A WIND-PROOF UMBRELLA

the umbrella open, is so extremely simple that it is surprising this little artifice has not been introduced before. We are again reminded of the story of the egg of Columbus.

THE GALVO-FILTER.

An efficient and compact household filter is a great desideratum. Perhaps the one shown herewith possesses as great advantages as any which have come to our notice. As will be seen from the illustration, it consists of a nozzle to be attached to a faucet, and having at its central portion an enlargement or bulb containing the principal filtering medium, such as granulated carbon. At the upper entrance to the bulb is placed a fine metal gauze partition, and the bottom is closed by a perforated plate made in three thicknesses, consisting respectively of copper, zinc

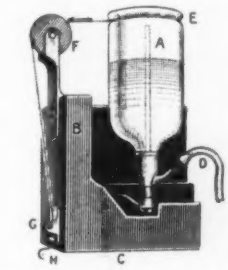


THE GALVO-FILTER

and bronze. This lower partition is electrically connected to the upper plate of metal gauze, and the inventor claims that through the galvanic action thus set up a particularly beneficial germicidal action is produced. While we may feel very skeptical as to the soundness of this claim, it appears that quite apart from this feature the device presents advantages which should commend it for general use.

AN IMPROVED GAS GENERATOR FOR THE LABORATORY.

Our illustration shows how, by a very ingenious twist, the ordinary type of soda water bottle may be used as a reservoir or generator for various gases which are commonly used in the laboratory, such as carbon dioxide or sulphur dioxide. Such a bottle, containing the ordinary artificial carbonated water, or, if sulphur dioxide is the gas required, a quantity of this substance liquefied at a pressure of about three atmospheres is inverted and, in any suitable manner, fixed upon a stand *B*. This is provided with a pulley *F*, over which passes a cord attached at one end to the grooved foot of the bottle, and slipped at the other end under a clamp *G*. The bottle rests upon its head, normally in a vertical position, but is free to move about that head as a pivot in the plane of the illustration. If the cord is pulled, the lever of the valve abuts against the inclined shoulder *b* of the wooden support, thus opening the exit from the bottle. As the bottle is inverted, and the siphon tube projects upward into the space above the liquid, gas only escapes through the valve. When the rate of escape is adjusted to suit the convenience of the user, the cord is fixed in the corresponding position by means of the

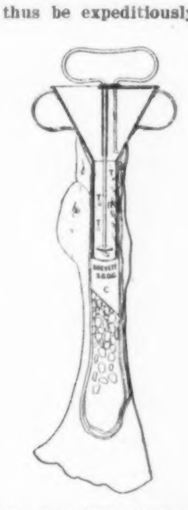


AN IMPROVISED GAS GENERATOR FOR THE LABORATORY

clamp *G*. When we remember the many inconveniences attending the use of Kipps's apparatus and its various modifications, especially for the production of noisome gases used in the analytical laboratory, it appears that this very simple and cheap device should find ready acceptance wherever a supply of such gases must be kept at hand.

MECHANICAL FEEDER FOR FATTENING POULTRY.

An instrument which is calculated to relieve the suffering to which animals are subjected in forced feeding, and which at the same time adds rather than detracts from the efficacy of the operation, should find a welcome among the more humane of those engaged in this branch of poultry farming. The general character of the device will be obvious from a glance at the accompanying diagram. The feeder is provided with a piston the disk of which automatically adjusts itself in a vertical position during the upward motion of the piston rod, and in the horizontal position during its downward motion. The food introduced into the funnel can thus be expeditiously crammed down



MECHANICAL FEEDER FOR FATTENING POULTRY

the bird's throat, while at the end of its downward journey the piston is free to be retracted, since the disk turns over, so as to allow air to enter. The tube of the instrument is capped with a rubber covering, which protects the throat of the animal from injury. In order to admit air and allow the bird to breathe during the operation, the sides of the funnel tube are provided with flutings *R* of sufficient depth to insure access of air. A number of holes *T* admit the mucous secretion of the throat, thus providing a kind of lubrication which facilitates the removal of the tube.

Packing Glands.—For a cement for making stuffing-boxes and piston rods of steam engines tight, take 5 parts of rubber, 2 parts gutta percha, 1 part sulphur, 1 part pulverized graphite, 1 part silicate of magnesia, 10 parts filings of copper, zinc, lead, tin or alloys of these metals.

* *La Nature.*

Chemical Research and Industrial Progress*

What Commerce Owes to Chemistry

Within the last few years research has become a word to conjure with. Webster defines it as "diligent inquiry in seeking facts or principles, continuous search after truth." To find the truth is, therefore, the keynote of research. But although the great activity in research which so marks the present is essentially modern, an inquiry after truth is surely not new. The human mind has from the gray dawn of antiquity longed for and sought after truth. The new field of human endeavor epitomized by the word research represents a change in the method of finding truth rather than in the intensity of desire to know the truth. When a great thinker of the past wished to investigate a subject he simply sat down in a quiet nook or walked through academic groves and philosophically meditated concerning it. He believed that he could know things as they are and had great faith in the accuracy of his conclusions. As a mental performance such philosophical labor was not altogether without value—but since we cannot know things as they are, but must know them as they appear or manifest themselves, a search for truth can reach its goal only through intimate contact with the things themselves, and an accurate determination of the facts concerning them.

At the time when the followers of Aristotle were speculating upon the constituent parts of the universe, and concluding that everything was composed of fire, water, air and earth, with the material transformations which each could undergo, there were other men who were devoting their attention to the real transformation which materials do undergo. These people had glass, a product showing a marked change when compared to the raw materials going into its production; they were able to dye the royal purples and to bleach the fine linens. They had the knowledge to smelt iron and copper, tin and lead from their ores—surely striking transformations which they could actually see. But the truth concerning these phenomena did not interest the men the achievements of whom history has seen fit to chronicle. The dictum of Aristotle that "industrial work tends to lower the standard of thought" prevailed, and it is to this want of sympathy that we must ascribe the fact that the old historians failed to note the discovery of even the most important chemical processes, while they gave detailed accounts of those men who advanced mere speculations and taught untenable opinions on the constitution of the universe.

But groping in the utter darkness of these early times, the men who actually did things in the utilization of natural phenomena in contradistinction to their more famous brethren who only talked and idly speculated about them, were the real pioneers in chemical research. Their quest for truth was, however, so crude, and their endeavors so little appreciated, that almost no real progress was made. The teachings of the philosophers that there was required but the "quinta essentia" in order to transform one of their four elements into another, together with accidental observations on the part of some pseudo-scientists, led to that studied attempt to transmute the baser metals into gold which lasted for many centuries. If but the "Philosopher's Stone" could be found, the problem would be solved. This was the goal of the alchemists. It would be a perversion to describe the labors of these men as a search for truth; their objective point was gold, not truth, and many a devoted life was spent in this fruitless quest.

It may seem a long step from the work of the alchemists with all their magic and mysticism, their sordid lives, and their cherished secrets, to the consideration of the intense human activity of the present day with those gigantic undertakings and marvelous achievements, collectively called modern industry. But there may be something in common between the work of the ancient investigators and their influence on civilization, and chemical research of to-day and industrial progress.

The course of human events has been compared to a pendulum. We tend to swing to extremes; to go too far, first in one direction and then in the other, when real progress lies in the middle. The period of alchemy represents the pursuit of science for selfish and mercenary ends; they cared for nothing but to be able to make gold. The pendulum was at an extreme end of its path. Nor did they make material progress in their methods. The alchemist of Arabia and early Germany were little wiser than their predecessors of Egypt who flourished many centuries before them. The explanation of this lack of progress is to be seen in the profound secrecy which they at all times maintained. When some enterprising worthy did take it upon himself to transcribe for future generations his knowledge of the mystic art, his sentences were so ambiguous and his diction so involved as to make the whole entirely meaningless. They even employed mysterious symbols to render the more difficult any attempt at imitation.

There was, therefore, no accumulation of knowledge or experience, and each succeeding investigator continued to grope around in the darkness which had ever enveloped his calling, without deriving any benefit from the labor of either his predecessors or his contemporaries. The great and insurmountable obstacle to progress was nothing more than the jealous secrecy engendered by selfish competition. Both confidence and co-operation were entirely wanting. Each one feared that his neighbor might profit by his experience were it to become known, never realizing that he must in the end get much more in return than he gave. There was but one of him, while there were many of his neighbors.

But in the thirteenth century there came a change. One Roger Bacon, who from his rare accomplishments and erudition was called Doctor Mirabilis, and who firmly believed in the existence of the philosopher's stone, was being tried at Oxford for sorcery. To disprove the charges against himself, he wrote a celebrated treatise with a long Latin name, in which he showed that phenomena, which had been attributed to supernatural agencies, were in fact due to common and natural causes. He pointed out further in his brief a possible distinction between what he called theoretical alchemy, or work which would advance the knowledge of natural phenomena, and practical alchemy, or the striving after immediately usable information. He is to be regarded as the intellectual originator of experimental research, and by his generous treatment of the knowledge gained, gave to the science the impetus for which it had so long waited. The limitations of this paper preclude my following in any detail the development of chemistry through the succeeding centuries, but it can be easily shown that just as knowledge was sought after for its own sake, and in proportion as there was free and honest intercourse among the investigators of the time, just so rapidly was real progress made.

With the appearance of men who took an absorbing interest in the study of natural phenomena for the purpose of gaining a deeper insight into the world around them, when investigations were undertaken from a desire to know, and to acquire knowledge which could become the property of the world at large, the pendulum began to move back.

For years the efforts of investigating minds were devoted to the explanation of the phenomena of nature; to the discovery of new laws and principles; to the accumulation and organization of facts, into what is called a "Science," to a real search for truth. This resulted in a general uplift of humanity, and advance in civilization, which cannot be described or measured in a few words. It was a time when the human mind was struggling to determine realities in the midst of tradition and superstition; to realize that nature is always complex but never mysterious; their dependence should be placed in proven facts rather than the vagaries of priests and philosophers. Man became intellectually free.

But for many years after the broad generalizations upon which modern chemistry is founded were well established, industry did not profit much by scientific work. One hundred years ago the men who smelted the iron and copper, the lead and zinc, knew little of the principles underlying their practice. Leather was tanned, woolens, cottons and silks were dyes, porcelain and glass were made, without the aid of those who alone knew the chemistry involved. I do not mean that scientific men took no interest in the manufacturing industries, for we can recall the great work of Liebig for agriculture, and the immense amount of analytical chemistry which is the foundation of industrial chemical practice; but there were times when the advance in chemical knowledge was far ahead of the industries on the success of which our material comforts depend. The pendulum had swung to the other extreme.

A rational attempt to apply chemical knowledge and methods commenced about 1850. It was in 1856 that Perkin made the first synthesis of a coal tar color, and founded the industry which has become the most remarkable example of applied chemistry that we have. In 1855 Bessemer introduced his revolutionary process for making steel, made possible by the clear understanding of the nature of steel through improved analytical processes.

Up to this time when a man became a student of chemistry, it was because of the attractions which he found in scientific study; because of his "delirious but divine desire to know." On the other hand a man who intended to devote his life to the carrying on of some industry did not study chemistry at all, or if he did it was in a superficial and most perfunctory way. With the establishment of great technical schools there was produced a class of men who, notwithstanding the fact that they intended to follow industrial work as a career, studied chemistry in such a way as to become masters of the fundamental principles underlying the science, as well as possessors of a great mass of scientific knowledge and experience. Possibly more important even than this, they became imbued with the scientific method of thought and work. Such men carried science into the industries and applied to the solution of the practical problems of the day the knowledge of chemistry which was theirs. Hence the last fifty years may be said to be characterized by the production of men who combined the ability to appreciate and enjoy work in science for itself alone, but also possessed the ability and inclination to apply their chemical knowledge and training, and to make the results of past generations of pure scientists of ever-increasing service to humanity.

But within the last ten or fifteen years we have seen a third kind of chemical activity develop, namely, a class of men who while possessed of the ability and love of science which characterized the leaders in pure science of old, yet are not handicapped by the doctrine of Aristotle, that contact with industry contaminates thought. This movement is seen in the tendency of great industrial organizations to establish research laboratories within themselves, and in the willingness of educational institutions to maintain research work in these fields of chemistry which are immediately applicable to industrial practice.

For the purpose of further studying the relationship existing between chemical research and industrial progress, we may therefore divide this kind of chemical activity into three classes: First, we have that which for want of a better term we will call original work in pure chemistry; second, we must consider the work of the so-called industrial chemist, the man who primarily applies existing chemical knowledge to the accomplishment of specific ends, and third, we have research work in what again, for want of a better name, we will call applied chemistry.

It is but a truism to say that there is no more dignified, honorable, or altogether delightful calling in life than the pursuit of science for her own sake. The biographies of the great altruists of science are ever an inspiration to the student of human progress. The man who devotes his life to the accumulation and dissemination of knowledge without thought of return other than the gratification incident to discovering nature's secrets, and adding to the sum of the world's knowledge, is living in many respects an ideal existence. But such men must subsist, and if the results of their work bring no financial return they must have some vocation for which the world is willing to insure payment. Thus it comes about that for the most part our educational institutions have been the source from which such work has sprung. The environment of pure science has in the past been academic; its home has been in the schools of learning; the great investigators were teachers. Of course there are exceptions, but the honor roll of science is essentially an academic list. This is true in America as in Europe, and yet there is a very different attitude shown toward men of science and their work by the manufacturing public, here and in Germany, for example. There the dictum of the university carries authority, while our feeling is shown rather clearly by our very general use of the word *academic*. It is usually a term of mild contempt, and is used synonymously with impractical, unworkable, and a lack of acquaintance with cold facts. That great scientist, Prof. Wm. Ostwald, when addressing the Liverpool Section of the Society of Chemical Industry, on the causes of the great success of the German chemical industries, said in substance: "We might sum up the facts by saying that Germany managed to put more brains into her goods, or if ye prefer a more scientific expression, to combine more mental energy with the dough energies of primary material. There is no doubt that the English store of mental energy is as great as that of Germany, the only difference being that the channels leading that energy into industry were not so broad or deep or numerous as in Germany. There seems to exist in parts of Great Britain not only a disregard for, but even a mistrust

* Address of the retiring president of the American Electrochemical Society, New York, April 7th, 1911. Reprinted from *The Journal of Industrial and Engineering Chemistry*.

in science or theory. In Germany everybody trusted science, even the government. They were quite accustomed to consult a scientific expert before going into a new business. Of course there were cases in which they failed to act in this way, but then they generally fell into scrapes. Sometimes even theory led into scrapes, but it proved to be bad or incomplete theory. But the sum total of experience has convinced them of the value of theory, and their trust in it was rather too large than too small."

This statement does not apply alone to England. Our American industries have flourished very well, it is true, but rather in spite of a lack of scientific aid, than on account of such aid. This high regard with which science is held by even the less educated manufacturers of Germany, while undoubtedly the true bases of the splendid achievements resulting from co-operation of science and industry, is probably not to be realized in America in the immediate present. High respect for science is a characteristic of the German, and is possibly a result of years of military discipline as a part of a monarchial government. Can it be true that the spirit of freedom has run so riot in America that we now come to believe that we are not subject even to the laws of nature? Supplied with bountiful resources far beyond what any other nation enjoys, protected by a tariff wall higher and tighter than those of our commercial competitors, we have grown vastly satisfied with our own achievements. To quote from a keenly observant contemporary:[1] "We marvel at our enterprise in scraping iron ores from the earth's surface by steam shovels, in growing wheat on virgin soil, in stripping great areas of primeval forests, in burning natural gas, and allowing petroleum to spout from the ground. Even Germany acknowledges that she cannot compete with us in raising cotton, and we cut more ice in a month in the single State of Maine than all the Pictet machines in France can turn out in a year. We control the copper market of the world because we have the copper! If cheap sulphur is wanted, we pump it from the ground! We develop great centers of power distribution, because our rivers run so fast down hill! To these vast resources we have, indeed, brought a native energy, an unusual capacity for organization, and a genius for mechanical affairs. What we do we do on a large scale, but we often do it very badly. It is quite time for us to pause in our self-congratulation long enough to inquire whether the things we are doing cannot be better done, whether, in fact, other nations have not developed and put to use much better methods, which, given an equal opportunity, put our performance to the blush."

There is thus a mutual obligation existing between our educational institutions and our industries. The former must continue to increase their facilities for the research, which has made the German universities the avenues through which German civilization and industry have been brought to the point that we find them to-day.

On the other hand, the industries should not fail to recognize that progress based alone on industrial prosperity is but apparent progress, and that a sound civilization depends not only on conditions which make for material comfort, but on the culture which comes from an education, the broad sense that scientific research implies.

The great tendency of our times is toward service. This is seen in every sphere of human activity. The philosophy of even one hundred years ago was largely speculative; while doubtless mentally invigorating, it did not in the last analysis contribute toward that progress which alone makes life worth the living. As a result, all past systems of philosophy have been thrown back into the realm of literature or of poetry. The trend of modern philosophy is toward a study and realization of things as they manifest themselves, and not a mere guess at what things probably are.

In religion, too, we note a change. There was a time when the main object of one's religion was to save one's own soul, without much regard to the souls of others. But we no longer recognize particular virtue in shutting one's self up within heavy walls, in order to render one's life more pure, because of lack of contact with the great mass of humanity. We no longer admire the self-sacrifice of the immured monks of Thibet—we simply pity them. Religion is to-day the great inner consciousness, which renders one's own future condition secure by aiding the present condition of others. The great religions of to-day make for righteousness through service.

In the same way there is with scientific men a general awakening to the fact that the highest destiny of science is not to accumulate the truths of nature in a form that no one but the elect few can utilize, but that the search for truth can be combined with a judicious attempt to make the truth serve the public good. Thus the distinction which has existed between the terms pure science and applied science is rapidly falling away. An attempt to define these two kinds of science reveals the fact that their distinction is a general impression rather than a clear statement. A fundamental law of psychology is that thought tends to pass over into action. Applied science is nothing more than the realization of this, and is thought in action. Force does work only when in motion—so are ideas of value, only when carried into effect.

But the carrying of an idea into practice is not always an easy matter. It is frequently much easier to make a discovery or to develop a new fact than it is to make of such a discovery a serviceable reality. For example, the reactions underlying the ammonia-soda process were well-known as scientific facts for many years; but this knowledge did not benefit the world until the genius of Solvay made through it purer and cheaper soda available. Cavendish long ago discovered that an electric spark produced nitric acid in the air; the world waited until but a few years ago in order to profit by this knowledge. It was then that the researches of Birkeland and Eyde made of the idea an industrial process.

Many facts like this last were known which did not materially influence the industries of the times because there was necessary a knowledge of how to obtain and apply large quantities of electrical energy. Thus Wöhler discovered the reaction by which phosphorus could be readily distilled from a mixture of bone ash, sand and coke; but it remained for Readman and Parker to apply internal heating by electrical means to thus make phosphorus. Wöhler also discovered calcium carbide and its property of yielding acetylene. The beautiful light from this source was not made possible, however, until the development of high-powered electric generators made its cheap production an easy matter. Men who can interpret the scientific results already available have been of incalculable value in the growth of our industries, and there will ever be a field for this type of chemical activity. In fact it is just here that we find the faith in science of the Germans of which I have spoken bearing fruit. In America there is a national lag in the application of new scientific data to every-day problems. We as a people are so wonderfully keen in developing mechanical ideas when once they are presented that the marked lag in the acceptance and application of chemical principles is remarkable. The industries themselves are frequently to blame for disappointing results which sometimes are met in an attempt to introduce scientific methods into their works. They employ a so-called chemist, without inquiry as to whether he has had the kind of training that could be expected to fit him for the work he is to do. They furnish him with a meagre equipment and then expect revolutionary results. When these are not forthcoming they exclaim in disgust: "There is no money in chemical control, or in chemical research—we have tried it." It is just as though I should decide to increase my income by adding to my other activities that of horse racing. I buy a well-meaning, but untrained horse, and enter him for the race. He fails to win the purse, and I exclaim: "There is no money in horse racing, I've tried it." Or probably my analogy would be more complete if I would suppose that I bought a well trained, capable horse, and then hitched him to a coal wagon or an ice cart, and started him off. Then because he fails to win out over the horses in racing sulkies, I again affirm. "No, there is no money in horse racing, I've tried it."

While it is true that the manufacturing industries as a whole have been slow in accepting the aid of science, and while the American public lack the belief in the part which science plays in the advance of the world possessed by some other nations, there is a distinct and most promising movement under way, which will have a marked effect upon our industrial progress. This is the impatience shown by some of the more enterprising manufacturing concerns, to wait for scientific facts to be discovered by others, and their willingness to establish research laboratories within their own organizations; to actively enter the field of research in applied chemistry.

From what has already been said, there may appear to be a paradox in the expression research in applied chemistry. How can the element of research enter into the work of applying to definite ends the facts already established as true by others? Is there a difference between research in so-called pure chemistry, and research in what, for want of a better name, we will call applied chemistry? Possibly I can make the distinction clear by a rough analogy. The development of research in a science may be compared to the exploration of a new country. New roads are to be laid out, tunnels bored, and bridges built; in other words new problems solved. This may be done in two ways. First, constructive work may be undertaken wherever an interesting problem presents itself, without regard as to whether there is a demand for such structure or not. It is built because of the interest of the builder in solving this particular difficulty, and the pleasure he takes in it, knowing also that sometime it will be utilized. As a rule he is under no great pressure to get the structure completed. This may represent the method of pure chemistry, and the great advance in chemical knowledge of the past was made almost entirely by boring just such tunnels, and building just such bridges. The industries have used these structures when they could or when some second builder could adapt them to use. Research in applied chemistry differs from that just described only in this—I should say it *needs* differ only in this, that when a problem is to be solved, a bridge to be built, the work is undertaken at a point where there is a demand for its use; where people are waiting to cross over, so soon as it is finished. The method of building is no different, the difficulties no less. The fact that the bridge is to be used makes the work of building no less dignified, nor is it possessed of less pleasure. In both cases the builder profits by all that has been done before, and contributes his bridge together with the new materials of construction which he may have found to those who may come after him. To cite an example from experience, suppose I were to determine the electrical conductivity of metallic oxides at high temperature, with great accuracy, and publish the results without reference to any particular application of the data. This is pure science. But suppose I am trying to perfect an electrical heating unit for high temperatures, and in insulating my resister, I do this identical piece of work, namely, measure with great accuracy the electrical conductivity of metallic oxides at high temperatures, and again publish the results. This is applied chemistry. The work need not differ in the least degree. It can be as accurately done, and the conclusions as scientifically drawn. The mere fact that the data will be used for some practical end need not make the investigations any less scientific.

Why is there then not the respect for this kind of work as when a bridge is built with the knowledge that it may not be used for an indefinite period? Why then does an eminent writer a few months ago lament the fact that there is not more research "uncontaminated with the worship of usefulness?" Why does usefulness contaminate? I think it lies in this: The investigator of pure science works in the broad daylight, throws his product open for inspection, and invites all to come and use it when they can. In applied chemical research the spirit of the alchemist tends to creep in. The builder keeps his materials of construction, and his designs, a secret, and so boards up his bridge that those who cross over it cannot see how it was built, nor profit by his experience. The moment a thing becomes useful we become jealous of its possession; we become narrow in our horizon; we sell our scientific birthright for a mess of pottage; we become alchemists.

There is a heavy moral obligation on the part of large industrial organizations having fully equipped research laboratories, to contribute their share to the advance of the world's knowledge. An obligation to see to it that they do not become saturated with the spirit of alchemy. They have well stocked libraries, and are provided with all the current periodicals; they profit by all the scientific work which has been done and is being done. This is as it should be, and such firms are to be commended for their progressiveness. But is this not a reason why such laboratories should do their part in adding to the sum of available knowledge? There is in every laboratory much work which could be published and yet conserve the interests of the corporation. First there are the results which may not have proved valuable to the laboratory in which they were obtained, but which would be of immense value to some one else working in an entirely different field. Second, there are those results of value to the laboratory possessing them, but which could be published in an unapplied or "pure" form and which would make an important contribution to science, and at the same time the publication would work no injury to the company or the corporation most interested. And finally there are those results of operations and processes, machines and apparatus, which if the truth were known are possessed by a number of concerns, but are held as valuable secrets by each. Every one would profit and no one be the loser by so far-sighted and generous a policy. Germany is very justly held up as a shining example of marvelous industrial progress and prosperity. A very great deal of the credit for her present position is due to her splendid educational system. But no small factor in her national progress is the helpful attitude which her industrial organizations take toward the publicity of scientific data. The individual does not suffer, while Germany both from a purely scientific and an industrial standpoint is rapidly advanced. But too often with us the president and his Board of Directors are alchemists; they

[1] Arthur D. Little in "A Laboratory for Public Service."

fail to see why if they pay the salaries of the research men, they should give to the public or their competitors any part of their results. They exclaim: "What has posterity done for us?" They would have their laboratories remain the secret chambers of the alchemists, and continue to improve their methods of changing baser materials into gold, without regard to the obligations which they owe their fellows.

It is to the men who form the working force in our industrial laboratories that we must in a great measure look for making our national scientific societies the power for industrial progress which they ought to be. But it is this general disinclination on the part of industrial concerns to allow their chemists to disclose in any measure the results of their work by contributing papers for the meetings, or in entering heartily into the discussions that make this realization difficult. This is to be deeply lamented, and we believe it is a fundamental mistake; a short-sighted policy which can but react upon industrial progress as a whole. We cannot operate a scientific laboratory as we would do a factory. The conditions of maximum productiveness are not found in an atmosphere of selfish rivalry. An English writer of broad technical experience has said when speaking of the cry for technical education: "Until the nation, as a whole, recognizes that the prosecution of scientific study as a mere means of money making is a profanation defeating its own ends, the history of the industrial development of England will afford the same melancholy spectacle in this as in the last century, technical education notwithstanding." All attempts at machine-made scientific results are doomed in the long run to failure. They compare with the achievements of men working under conditions of mutual helpfulness as does a machine-made Nottingham curtain compare to the beautiful hand-made lace of the French convents.

It requires no extensive mathematical calculation to prove that the manufacturers themselves would be the ones to profit by such a liberal treatment of the results of scientific work. Of one hundred manufacturing concerns, each one would give but 1 per cent of the whole contribution, while he would receive the remaining 99 per cent. He could not in the long run be the loser. But of vastly more importance, he would feel and know that his organization was taking part in a world movement toward that increase of human knowledge upon which all real progress depends. The greater sense of satisfaction, the greater success even of an industrial organization, lies in a fuller, freer, more generous publicity of the scientific results of their laboratories.[1]

Would that we might benefit by the experience of Solomon, King of Israel, who, when asked "What shall I give unto thee," replied, "Give me knowledge and wisdom," and he was answered, "Wisdom and knowledge are granted unto thee; and I will give thee riches and wealth and honor."

[1] Dr. Carl Otto Weber in "The Chemistry of India Rubber."

A New Spectroscope and Spectrograph

A Cheap Instrument Radically New in Design

By R. A. Houstoun, M.A., Ph.D., D.Sc.

The type of spectroscope for general use in physical or chemical laboratories is now pretty well fixed. There is a telescope and collimator, both with achromatic glass lenses, the collimator being fixed and the telescope moving round a divided circle. If the spectrum is to be photographed, the eyepiece end of the telescope is replaced by a box carrying a photographic plate at its end. With an instrument of this kind, work can be done in the visible spectrum and in the ultra-violet to about $330\mu\mu$; if we wish to go further, quartz lenses and a quartz prism must be used. Quartz lenses and a quartz prism will also carry us considerably further into the infra-red than glass. But the quartz prism in general use, the Cornu double prism, gives a sharp image only when set at minimum deviation, and the focal length of a quartz lens varies so rapidly with the wave-length that the photographic plate must be set with its surface at an angle of about 21 deg. to the axis of the camera. The focussing of the plate may thus be a lengthy process. On account of these complications and the cost of the special apparatus involved, the experimenter of moderate means and limited experience usually avoids the ultra-violet and infra-red.

The object of this short paper (from *Knowledge*) is to describe a cheap and simple form of spectroscope of radically different design, which is eminently suited for the amateur who wishes to work in these regions, and which is also suitable or the visible spectrum. In this instrument the lenses are replaced by mirrors, and the Wadsworth mirror-prism combination is used. The Wadsworth mirror-prism combination consists of a prism and mirror mounted together on the prism table, with the plane of the mirror and the plane that bisects the refracting angle of the prism both meeting in the axis of rotation of the prism table. The diagram (Fig. 1) illustrates a special case of the arrangement; *ED* and *CA* are respectively the traces of the two planes referred to, and they both meet in *A*, the point through which the axis of rotation of the table passes.

Now consider any ray *FGHJK* (Fig. 2) passing through the prism at minimum deviation, and being reflected by the mirror. Its path through the prism, *GH*, is parallel to the base of the prism *DB*, and *JK* is parallel to *FG*. From *A* draw *AP*, *AN* and *AM* perpendicular respectively to *FG*, *HJ* and *JM*. Then by symmetry $AP = AN$, and by equal triangles $AM = AN$. Consequently $AP = AM$. Suppose that the ray *FP* is white light; the color in this ray that suffers minimum deviation emerges along *JK* after passing through the system. Rotate the prism and mirror through the same small angle, keeping the direction *FP* fixed. Then *AP* and *AM* are fixed, and consequently *JK* is fixed. A different color now suffers minimum deviation, but emerges along the same straight line *JK*.

Suppose now that the single ray *FP* is replaced by a beam of parallel rays and that the prism table is rotated; each color in turn, as it suffers minimum deviation, is undeviated and at the same time suffers the same constant parallel displacement.

The next diagram (Fig 3) shows how these properties are taken advantage of. *ABCD* is a solidly-made box, the lid of which has been removed and into which we are looking vertically down. *S* is a slit attached to a piece of brass tubing which slides in a short piece of tube fixed in the side of the box. The light from the slit is rendered parallel by the concave mirror M_1. It is then acted on by the mirror-prism combination, falls on the other concave mirror M_2, and is brought to a focus on the photographic plate at *P*. The concave mirrors are placed at their calculated distances, and any necessary adjustment is then done by sliding in or out the slit until the image of the latter, when illuminated with Na. light, is perfectly sharp on the ground glass plate. Then, since the focal length of a mirror is independent of the color of the light, all the spectrum is in focus away into the ultra-violet.

Fig. 1.

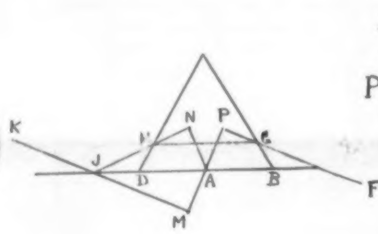


Fig. 2.

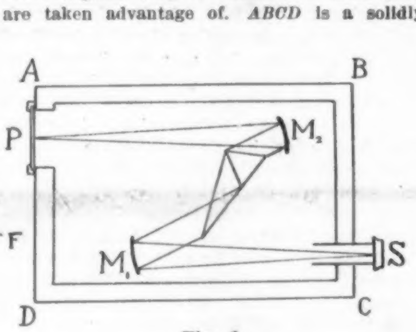


Fig. 3.

SPECTROSCOPE AND SPECTROGRAPH

Suppose that a quartz prism is being used, and that the photographic plate is replaced by a fixed eyepiece with crosswires. Then, if the mirror M_2 is adjusted so that the Na. lines coincide with the crosswires when they are at minimum deviation, and the prism table be rotated, every line comes into minimum deviation as it reaches the crosswires. That is, we obtain maximum definition automatically. The same holds if we are examining the infra-red with a linear thermopile. The thermopile remains fixed and we move the spectrum across it and every line as it reaches it moves into perfect focus, a pleasant contrast to the quartz spectroscope, where, for every wave-length, we have to adjust both for minimum deviation and the correct distance of the thermopile from the lens.

Other advantages of this mirror spectroscope are its compact form and the absence of diffuse light. When light falls on a lens, 8 per cent is reflected back; here the light not used is absorbed by the mirror. Also, there are no tubes to reflect light at grazing incidence. The instrument may also be used as a monochromatic illuminator.

For the mirrors I have used plate glass and cheap concave lenses silvered. As it is the outside surface of the silver that is used, it is better to send the glass to an optical firm to be silvered. In calculating the position of M_1 and M_2, allowance must be made for the obliquity of the incidence. The correct distance between *S* and M_1 or *P* and M_2 is not $r/2$ but $\frac{r\cos\phi}{2}$ where ϕ is the angle between the incident beam of light and the normal to the mirror.

The disadvantage of silver mirrors is that they reflect light at $310\mu\mu$ very poorly. Consequently, that part of the spectrum is usually wanting, although the region beyond comes out well enough. Spiegel magnalium mirrors, however, reflect well to the very end of the spectrum; I have no experience with them, but, according to the tables, if they are used, the spectrum should be everywhere as bright as with quartz lenses.

Trade Notes and Formulæ

Lubricant for Stuffing Boxes.—Paraffine 1 part, pulverized soapstone 4 parts, melt together and saturate cotton-wicks with the molten mixture. They are then packed in the stuffing boxes.

Lithographic Pencils or Lithographic Chalk.—The substance known as lithographic chalk consists of a black mass that can be sharpened with a knife, like a lead pencil. It must not be harder than a very soft pencil; that is to say, it must produce on the stone, with the lightest pressure, a perfectly black mark.

Stamps Made from Glue.—In place of rubber stamps, Gerhard, of Emden, makes stamps of glue. On the set up type, a few sheets of tinfoil are laid, and with the aid of a felt a single deep impression is made by means of a press. The tinfoil matrix is then taken from the mold and lightly oiled. About the matrix oiled lead sills are arranged, and joiners' glue, to which a little printers' roller mass has been added, is then poured in. After cooling this can readily be detached. For the first few days after casting the stamp remains somewhat soft, but subsequently hardens, without losing the elasticity required for a stamp. The stamps made by this quick and cheap process must, of course, be mounted on wooden handles.

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